UNDERSTANDING HOW SUMMER RESEARCH EXPERIENCES CAN FOSTER DIVERSITY IN COMPUTING RESEARCH

AMA NYAME-MENSAH
BURÇIN TAMER
JANE G. STOUT

CERP
Computing Research Association
Evaluation

Recommended citation:
Nyame-Mensah, A. Tamer, N. B. and Stout, J. G. (2015). *Understanding How Summer Research Experiences Can Foster Diversity In Computing Research*. Computing Research Association: Washington, DC. Available from: http://cra.org/cerp/research-findings/

To learn more about CRA's Center for Evaluating the Research Pipeline, please visit our website: http://cra.org/cerp. Questions regarding this report and/or requests for other related documents please contact: cerp@cra.org.

Center for Evaluating the Research Pipeline
Computing Research Association
1828 L St NW, Suite 800
Washington, DC 20036
p. 202-266-2937
f. 202-667-1066
e. cerp@cra.org

Table of Contents

4 Acknowledgments

5 About CERP

6 Executive Summary

7 Introduction

9 Evaluation Method

12 Results

15 Conclusion and Recommendations

17 References

19 Technical Appendix

acknowledgments

We would like to thank Dr. Betsy Bizot and Dr. Tracy Camp for their thoughtful comments on an earlier version of this report. We also thank Heather Wright, CERP Research Associate, for her contribution to data collection for this project.

CERP was created by the Committee on the Status of Women in Computing Research (CRA-W)/Coalition to Diversity Computing (CDC) Alliance through a National Science Foundation grant to the Computing Research Association (CNS-1246649). The current research was supported by NSF grant CNS-1246649. Any opinions, findings, conclusions, and recommendations are the authors' and do not necessarily reflect the views of the National Science Foundation.

CERP
Computing Research Association
Evaluation

CRA
Computing Research Association

the coalition to diversify computing

About CERP

The Computing Research Association's (CRA) Center for Evaluating the Research Pipeline (CERP) evaluates the effectiveness of intervention programs designed to increase retention of individuals from underrepresented groups in computing, namely men from underrepresented racial/ethnic groups and women of all racial/ethnic backgrounds. More generally, CERP strives to inform the computing community about patterns of entry, subjective experiences, persistence, and success among individuals involved in academic programs and careers related to computing. For more information about CERP, visit http://cra.org/cerp/.

Executive Summary

Computing students who participated in a summer undergraduate research experience (SURE) reported greater **intentions to pursue a Ph.D. program in computing** and stronger **interest in pursuing a computing research career** after college than non-participants.

To promote underrepresented students' (men of Black or Hispanic background and women) **intentions to pursue a Ph.D. program in computing**, we recommend SUREs focus on the following:

- Exposure to research skills
- Disseminating research results
- Information about the graduate admission process
- Information about graduate student life

To promote underrepresented students' **interest in pursuing a computing research career**, we recommend SUREs focus on the following:

- Collaboration with others
- Learning how computing research has a positive impact on society
- Learning about computing career options
- Exposure to research skills
- Learning how to work independently
- Disseminating research results
- Involvement in the design of a research project
- Information about the graduate admission process
- Information about graduate student life

Introduction

Student participation in undergraduate research activities is an established tool for enhancing the undergraduate experience and increasing students' motivation to pursue graduate study and, ultimately, research careers (e.g., Lopatto, 2004, 2007; Russell, Hancock & McCullough, 2007). Thus, undergraduate research experiences (UREs) appear to be an effective means to address the nation's growing need to produce more qualified computing researchers (Bureau of Labor Statistics, 2014). One strategy for strengthening the computing research workforce is to ensure that college students from diverse backgrounds are attracted to and retained within the computing research pipeline. At present, however, the vast majority of computing researchers are White and Asian men (Zweben & Bizot, 2015) – a population that represents a minority of the larger U.S. workforce and population (National Science Foundation, National Center for Science and Engineering Statistics, 2015). In response to the dearth of diversity in the computing research pipeline and growing concern about the domestic supply of computing researchers, many URE funding sources request that URE Principal Investigators recruit undergraduate student researchers from underrepresented populations (e.g., National Science Foundation, 2013).

The current report presents in depth research on students' experiences in summer-UREs (i.e., SUREs), with special focus on the experiences of underrepresented men as well as women (URMW; men of Black or Hispanic background and women of all races and ethnicities) versus majority men (MM[1]; men of White or Asian background). We first look at whether participation in SUREs influences URMW students' intentions to further pursue computing research compared to MM students. We then study a set of common SURE characteristics, and their relationship with URMW and MM students' intentions to persist in computing research.

Existing research indicates that URMW students tend to benefit more from UREs than MM students. For instance, URMW students show a greater degree of improvement in academic skills and educational aspirations after participating in undergraduate research than MM students (Campbell & Skoog, 2004; Chang, Sharkness, Hurtado, & Newman, 2014; Jones, Barlow, & Villarejo; Russell et al., 2007). This suggests that undergraduate research participation may motivate URMW students to pursue research careers to a greater degree than MM students. While this relationship has been hypothesized in the literature, this is an empirical question that, to our knowledge, has yet to be tested. As such, **the first goal of the current research** is to assess whether participation in SUREs has a different impact on MM students than on URMW students in their intentions to pursue a post-secondary degree in computing and computing research careers.

[1] We refer to this group as "majority men" (MM) because these demographic groups constitute the vast majority of students in computing degree programs (National Science Foundation, National Center for Science and Engineering Statistics, 2015).

The second goal of the current research is to assess whether common characteristics of SUREs are differentially related to intentions to pursue graduate study and research careers for URMW versus MM students. Although SUREs all share a common goal of exposing undergraduate students to scientific research methods, there is considerable variability in SURE program components. For instance, while some SUREs involve a great deal of collaboration and teamwork, others do not. UREs might also differ in social applicability of their research topic (e.g., Robotics research with medical versus industrial applications). Women, as well as men from underrepresented minority groups, tend to be attracted to technical fields when they are collaborative and have clear social applications (Diekman et al. 2010; Stephens et al., 2012), suggesting that these particular SURE traits may foster interest in pursuing research in the future among URMW students in particular. Moreover, underrepresented URE students are less likely than their MM peers to have had prior exposure to research training and mentorship (Bova, 2000; Stanley & Lincoln, 2005; Committee on Science, Engineering & Public Policy, 2011). As such, technical training and mentorship during SUREs may have a stronger association with URMW students' intentions to pursue a graduate degree and research career compared to the intentions of MM students. Thus, there is reason to believe that particular SURE characteristics might be effective in promoting URMW students' interest in pursuing computing research.

The current report presents in depth research on students' experiences in summer-UREs (i.e., SUREs), with special focus on the experiences of underrepresented men as well as women (URMW; men of Black or Hispanic background and women of all races and ethnicities) versus majority men (MM; men of White or Asian background).

Evaluation Method

Participants

During fall of 2014, 4,061 undergraduate students from computing departments across the United States were recruited to complete the Computing Research Association's Center for Evaluating the Research Pipeline (CERP) annual student survey[2] . The current report focuses on a subset of measures from CERP's Fall 2014 survey that assessed students' academic and career intentions, and experiences during a SURE.

We measured whether or not students had participated in the following research experiences:

- Summer research internship in industry or a government lab
- Summer URE at their home institution
- Summer URE at another institution

Students who had participated in a SURE were then asked a series of follow-up questions concerning characteristics of their SURE experience. A complete list of the **characteristics** we analyzed can be found in the **Research Design** section.

Of the 4,061 students surveyed, 1,558 (38%) were included in data analysis because this subgroup of students completed all survey items for the variables used in this report, were enrolled in an undergraduate computing degree program at the time of survey, specified that they intend to attain their highest degree in a computing field[3], and indicated whether they had participated in a SURE. The sample used for analysis included 101 SURE participants and 1,457 Non-SURE participants.

Within our dataset were two demographic subgroups of interest. The first was underrepresented minority men, including those of Black/African American or Hispanic/Latino descent, and women of all racial and ethnic backgrounds (URMW students). The second group was White and Asian men; we refer to this group as "majority men" (MM). Within our working sample (N = 1,558), 52 were URMW SURE students and 49 were MM SURE students; 546 were URMW Non-SURE students, and 911 were MM Non-SURE students.

Research Design

Our research design focused on addressing two research questions. Each research question is outlined below, along with variables used to assess each research question described at a conceptual level. See **Variables** section in the Technical Appendix for the exact measures used in this report.

[2] CERP administers an annual survey each fall semester to undergraduate student computing majors from a sample of universities and colleges across the county. Survey questions pertain to past research and professional experiences, with a particular focus on factors relevant to career preparation. For more information about CERP's survey research, visit www.cra.org/cerp/data-buddies.
[3] Computing fields included: computer science; computer engineering or electrical and computer engineering; computing information systems or information systems; or another field with a strong computing component.

Research Question 1 (RQ1): Does participation in a SURE differentially relate to intentions to pursue a post-secondary degree and interest in a computing research career for URMW vs. MM students?

What follows is a list of variables used to test RQ1. See Figure 1 for a spatial representation of the relationships between variables used to assess RQ1.

Outcomes

Students' post-secondary academic intentions

Interest in a computing research job

- As a College/University professor
- In industry or a government lab

Predictor

SURE participation (Yes vs. No)

Moderator

Demographic group (URMW vs. MM)

Covariates[4]

First-generation status (First-generation student vs. Non-first-generation student)

Class standing (i.e., 1st year student, 2nd year student, etc…)

Department type (i.e., highest computing degree offered in department is a B.S. vs. M.S. vs. Ph.D.)

Major grade point average

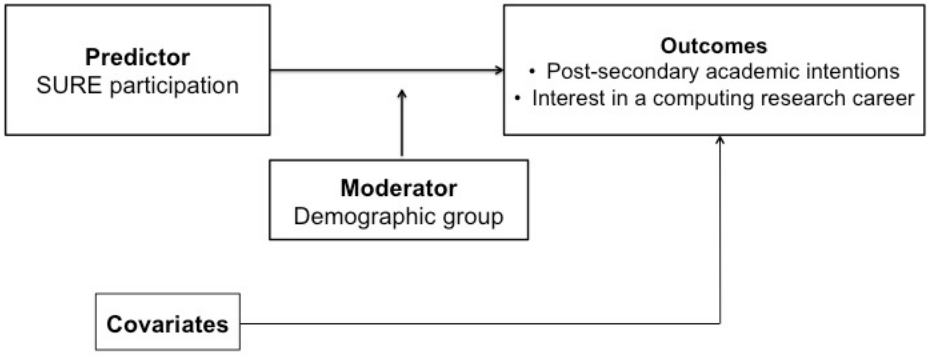

Figure 1: Analytic Model used to test RQ1

[4] Covariates are known correlates of outcome variables, and are included in statistical models so that any observed effects of predictors and moderators on outcome variables are true controlling for the effects of our covariates on outcome measures.

Research Question 2 (RQ2): Do characteristics of a SURE differentially relate to intentions to pursue a post-secondary degree and influence students' intentions to pursue a computing research career for URMW vs. MM students?

What follows is a list of variables used to test RQ2. See Figure 2 for a spatial representation of the relationships between variables used to assess RQ2.

Outcomes

Students' post-secondary academic intentions

Influence of SURE on intentions to pursue a computing research career

Predictors: Nine SURE characteristics

Collaboration with others

Learning how computing research has a positive impact on society

Learning about computing career options

Exposure to research skills

Learning how to work independently

Disseminating research results

Involvement in the design of a research project

Information about the graduate admission process

Information about graduate student life

Moderator

Demographic group (URMW vs. MM)

Covariates

First-generation status (First-generation student vs. Non-first-generation student)

Class standing (i.e., 1st year student, 2nd year student, etc…)

Department type (i.e., highest computing degree offered in department is a B.S. vs. M.S. vs. Ph.D.)

Major grade point average

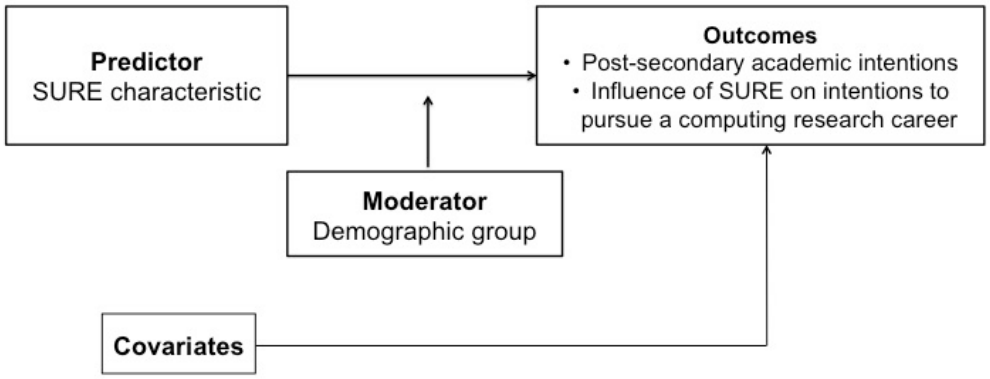

Figure 2: Analytic Model used to test RQ2

Results

Analytic Strategy

We conducted a series of moderated multiple regression analyses to address our two research questions. A "moderation" (or interaction) effect occurs when the relationship between a predictor variable (e.g., a SURE characteristic) and an outcome variable (e.g., students' intentions to pursue a Ph.D. in computing) depends on a moderator variable (e.g., demographic group: MM vs. URMW). As an example of a moderated relationship, suppose that students who are exposed to a higher degree of collaboration in their SURE (predictor variable) are subsequently more interested in pursuing a Ph.D. in computing (outcome variable). However, the relationship between exposure to collaboration and Ph.D. intentions is stronger for one demographic group of students than another (moderator variable). Specifically, SUREs fostering collaboration are particularly likely to promote interest in pursuing a Ph.D. in URMW students, relative to MM students. Thus, moderation analyses can explain "when" and "for whom" the effects of a predictor variable are related to a particular outcome.

A Note on Reporting

In what follows, we report only on the impact of our primary variables of interest (predictors and moderators), and do not present results concerning our covariates. All of the following findings were significant at the $p < .05$ level. For a thorough report of our statistical techniques and output, please see **Technical Appendix**.

RQ1: Does participation in a SURE differentially relate to intentions to pursue a post-secondary degree and interest in a computing research career for URMW vs. MM students?

To examine RQ1, we assessed students' post-secondary degree intentions and career interests as a function of (a) whether or not they had participated in SURE and (b) whether they were a URMW or MM student. It is important to note that students were not randomly assigned to participate in a SURE. Rather, students' participation in a SURE tends to be influenced by SURE admissions requirements including, but not limited to, the following: major GPA; class standing (2nd and 3rd year students are typically given preference); demographic group and first-generation status (underrepresented students, who are often first-generation students, are typically given preference); and department type (students coming from non-research intensive departments are often given preference). As a result, differences between SURE and Non-SURE participants' academic and career interests may be explained by a variety of student-level factors other than SURE participation. To control for pre-existing student-level differences between SURE and Non-SURE participants, we culled a subsample of Non-SURE participants (n = 101) that shared demographic characteristics similar to SURE participants using propensity score matching. Propensity score matching is an analytic technique that "matches" individuals from a treatment group

(e.g., SURE participants) to individuals from a comparison group (e.g., Non-SURE participants) who are as comparable as possible on a set of relevant individual-level characteristics (Shadish, Cook, & Campbell, 2002; Bai, 2015). In the analyses that follow for RQ1, our matched sample SURE participants and matched Non-SURE participants was N = 202. For more information on propensity score matching, please see Technical Appendix, **Propensity score matching**. For descriptive statistics for the RQ1 sample's demographics, see **Table 1** in the Technical Appendix.

The results in this section are presented by outcome measure. Within each outcome section, we present the results of our regression analyses. For descriptive statistics for URMW vs. MM students who were Non-SURE vs. SURE participants for RQ1 outcomes measures, see **Table 2a** and **Table 2b** in the Technical Appendix.

Students' post-secondary academic intentions

Students were asked to indicate their highest intended degree in a computing field from the following options: B.S., M.S., and Ph.D. Multiple regression analyses indicated that for both URMW students and MM students, participating in a SURE increased the likelihood that they intended to pursue a Ph.D. rather than a B.S. or an M.S.

> ***"The experience of working on an original problem and working through the challenges was stimulating."***
> ***– URMW SURE participant***

Students' Interest in computing research careers

For all students, participation in a SURE was unrelated to interest in getting a job as a college or university professor. Importantly, while all students showed a positive relationship between SURE participation and interest in getting a job as a computing researcher, the strength of this relationship was stronger for URMW students than MM students.

> ***"First hand insight and experience into research at a world-class university... showed the excitement, but also the difficulties that come with a research-based career."***
> ***– URMW SURE participant***

RQ2: Do characteristics of a SURE differentially relate to intentions to pursue a post-secondary degree and influence students' intentions to pursue a computing research career for URMW vs. MM students?

We ran multiple regression analyses to assess whether the relationship between nine SURE characteristics and our outcomes of interest varied depending on students' demographic group (URMW vs. MM). For descriptive statistics for the RQ2 sample's exposure to SURE characteristics and demographics, see **Table 3** in the Technical Appendix.

For descriptive statistics for URMW vs. MM student's outcomes for RQ2, see **Table 4** in the Technical Appendix.

Students' post-secondary academic intentions

Multiple regression analyses indicated that several SURE features had a positive impact on the likelihood of URWM students' plans to obtain a Ph.D. instead of a B.S. or M.S.

URMW students' plans to obtain a Ph.D. versus B.S. degree in computing was stronger when their SURE increased their research skills, informed them about research dissemination process, taught them about the graduate school admissions process, and indoctrinated them into graduate student life in computing fields. The only SURE characteristic that was related to intentions to pursue a Ph.D. rather than M.S. was exposure to the graduate school admissions process

For MM students, involvement in the design of research increased interest in pursuing a Ph.D. instead of a B.S. or an M.S. No other SURE characteristics were related to MM students' post-secondary intentions.

> ***"It was cool to work on a project that was bigger/more important than my coursework."***
> ***– URMW SURE participant***

Students' Computing Research Career Intentions

Exposure to each SURE program characteristic was positively related to the URMW students' intentions to pursue a computing research career. By contrast, exposure to none of the SURE characteristics was related to MM students' computing research pursuits.

> ***"...this program provided me with the best summer of my life."***
> ***– MM SURE participant***

Conclusion and Recommendations

Conclusion

This research was designed to better understand whether and how SUREs are an effective means for promoting diversity in computing research. We found that students who participated in SUREs reported greater intentions to pursue a Ph.D. and interest in pursuing a research career outside of academia than SURE non-participants. These findings are in line with prior work documenting the beneficial nature of UREs on students' future engagement in research (Lopatto, 2004, 2007; Russell, Hancock, & McCullough, 2007).

In our second set of analyses, we examined whether nine common SURE program characteristics were associated with students' intentions to pursue computing research in the future, and whether any of these program characteristics were particularly important for URMW students. We found that URMW students who experienced improvements in research skills, gained experience with the research dissemination process, were exposed to the graduate school admissions process, and learned about graduate student life during their SURE reported stronger intentions to pursue a Ph.D versus B.S. When it came to interest in pursuing a computing research career more broadly, our results also showed that experiencing greater exposure to all SURE characteristics we measured strengthened URMW students' interest.

The results of this report suggest that SUREs are an effective means for improving all students' intentions to persist within computing research – particularly with regard to Ph.D. pursuit and non-academic research jobs. It is our hope that these findings will provide useful information for how Principal Investigators (PI) and affiliates might hone their UREs to be maximally beneficial for all students, with a special emphasis on qualities that may be particularly important for URMW students.

"I loved the support of the faculty and graduate students during the research experience. It made my visit much more memorable. They helped me understand the topic in which I was studying and were always there for me if I had questions."
– URMW SURE participant

Recommendations

The findings of this report have practical implications for PIs and affiliates who plan to develop or already run research experiences for undergraduate students and whose goal is to broaden participation in computing. Our recommendations are drawn from the key themes that emerged from our study.

HONE STUDENTS' RESEARCH SKILLS AND CREATE OPPORTUNITIES FOR RESEARCH DISSEMINATION

Our findings suggest that exposure to research skills and the research dissemination process during SUREs support URMW students' intentions to persist in the research pipeline. Given that many underrepresented students lack exposure to science and are unaware of the demands of a research career (Bova, 2000; Stanley & Lincoln, 2005; Committee on Science, Engineering & Public Policy, 2011), UREs that exposure URMW students to research techniques and publication methods may offer those students the ability to form a scientist identity and gain skills and knowledge that will prepare them for advanced degrees and careers in science. In-line with this, quite a few URMW students included in this study cited that the most satisfying parts of their SURE experience were getting the opportunity to conduct and disseminate their research and becoming a part of their institution's research community. For instance, one student commented that "First hand insight and experience into research at a world-class university in computing showed the excitement, but also the difficulties that come with a research-based career." We encourage SURE PIs to design undergraduate research programs that will provide students with an opportunity to do original research that is methodologically rigorous and create opportunities for students to produce and present publishable findings in the form of reports, papers, and/or posters.

> ***"I learned the process of doing research and the goals that must be set in order to produce good results." - URMW SURE participant***

EDUCATE STUDENTS ABOUT GRADUATE ADMISSION PROCESSES AND EXPOSE THEM TO GRADUATE SCHOOL LIFE

Although access to higher education by traditionally underserved groups has increased over the last forty years (Committee on Science, Engineering & Public Policy, 2011), many underrepresented students lack knowledge of higher education admission policies and have little insight into life as a student at the postsecondary level (Vargas, 2004). Our results suggest that URMW students who learn about the graduate admission process and develop an understanding of graduate student life during a SURE express greater intentions to pursue a Ph.D. in computing and a non-academic computing research career. One SURE participant highlights this in saying "I was able to see the wide spectrum of interdisciplinary research. Also, the graduate atmosphere was amazing." We recommends that SUREs provide students with an opportunity to learn more about graduate programs in computer science and teach students strategies for selecting and applying to graduate school. In addition, we suggest that SURE programs incorporate networking and mentoring opportunities with current graduate students in computing in order to offer undergraduate students a realistic view of life in graduate school.

References

Bai, H. (2015). Current issues on propensity score matching: Matching with/without replacement, common support, and sample ratio. In W. Pan, & H. Bai (Eds.), *Propensity Score Analysis: Fundamentals, Developments and Extensions.* New York, NY: Guilford Press.

Bova, B. (2000). Mentoring revisited: The black woman's experience. *Mentoring and Tutoring, 8*, 5-16.

Bureau of Labor Statistics, US Department of Labor (2014). Occupational Outlook Handbook, 2014-15 Edition: Computer and Information Research Scientists, Retrieved May 28, 2015 from http://www.bls.gov/ooh/computer-and-information-technology/computer-and-information-research-scientists.htm.

Campbell, A., & Skoog, G. (2004). Preparing undergraduate women for science careers. *Journal of College Science Teaching*, *33*, 24-26.

Chang, M., Sharkness, J., Hurtado, S., & Newman, C. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching*, *51*, 555-580.

Committee on Science, Engineering & Public Policy (2011). Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads. National Academies Press.

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science*, *21*, 1051-1057.

Jones, M. T., Barlow, A. E. L., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in Biology. *Journal of Higher Education*, *81*, 82–115.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, *3*, 270 - 277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *Cell Biology Education, 6*, 297- 306.

National Science Foundation (2013). Research Experiences for Undergraduates (REU). Retrieved from http://www.nsf.gov/pubs/2013/nsf13542/nsf13542.htm.

National Center for Science and Engineering Statistics (2015). Women, minorities, and persons with disabilities in science and engineering: 2015. Special Report NSF 15-311. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). The pipeline: benefits of undergraduate research experiences. *Science*, *316*, 548 –549.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Boston: Houghton Mifflin.

Stanley, C. A., & Lincoln, Y. S. (2005). Cross-race faculty mentoring. Change: The Magazine of Higher Learning, *37*, 44–50.

Stephens, N. M., Fryberg, S. A., Markus, H. R., Johnson, C. S., & Covarrubias, R. (2012). Unseen disadvantage: How American universities' focus on independence undermines the academic performance of first-generation college students. *Journal of Personality and Social Psychology*, *102*, 1178-1197.

Vargas, J.H. (2004). College knowledge: addressing information barriers to college. Boston, MA: The Education Resources Institute (TERI).

Zweben, S., & Bizot, B. (2015, May). 2014 Taulbee survey: Relentless growth in undergraduate CS enrollment; Doctoral degree production remains strong, but no new record. *Computing Research News*, *27* (5), available from http://cra.org/resources/crn-online.

Technical Appendix

This Appendix contains technical documentation of the data and statistical analyses outlined in the main text of this report. The Appendix first elaborates on the analytical context by providing information on data and sample selection. Second, it introduces the variables used in the analyses and provides descriptive statistics for these variables. Third, it describes the statistical models used to conduct the analyses. Finally, the statistical output for results discussed in the main text of the report is provided in tables.

Data

The dataset underlying this report comes from the Computing Research Association's Center for Evaluating the Research Pipeline's (CERP) 2014 Annual Fall Survey of undergraduate students enrolled in a sample of computing related majors at U.S. colleges and universities participating in CERP's Data Buddies Project. Among other things, the survey collects information on students' participation in SUREs and characteristics of those SUREs.

The first part of our analysis compares our sample of SURE participants (n = 101) to a propensity-score matched sample of non-SURE participants (n = 101; details on propensity score matching below). We then look only at data from SURE participants (i.e., omit non-SURE participants' data) in order to examine students' reactions to exposure to characteristics of SURE programs. Thus, whereas our first set of analyses consists of a sample of 202 students (SURE and non-SURE participants combined), our second set of analysis consists of 101 students (only SURE participants).

Propensity score matching

For RQ1, we use an analytic procedure that "matched" a subset of students who had not participated in a SURE (n = 1,457) to those who had participated in a SURE (n = 101). Specifically, we culled a subsample of non-SURE participants who "matched" our sample of SURE participants on a set of demographic characteristics (i.e., covariates) associated with pursuit of extracurricular research activities (major GPA, URMW, institution type, class standing, first-generation status). We used a "nearest neighbors" technique to cull our matched sample of non-SURE participants, which selects the most similar observation from the non-treated group for matching with each observation in the "treatment group." The similarity is determined by the covariates included in the propensity score estimation. Since this technique matches each SURE participant to a single non-SURE participant, our matched dataset includes a total of 202 observations. This matching strategy allows us to mimic a randomized controlled experiment design using observational data. That is, by ensuring that we are comparing groups of respondents who are not systematically different from each other in any predictable way other than their SURE participation status, we can increase the probability that any difference between the two groups is attributable to this main independent variable of interest.

Variables

This section contains survey items used in the current research. Items are presented separately for RQ1 and RQ2, and in the following order: Outcome variables, Predictors, Moderator and Covariates.

For multi-item Likert style constructs, reliability was determined using Cronbach's alpha (α). Alpha levels $\geq .70$ are considered acceptable. Items for each construct were averaged together to form composite scores. Individual items are listed below.

Outcome Variables

Students' post-secondary academic intentions (RQ1 and RQ2): Categorical variable with 3 possible values. Bachelor's Degree, Master's Degree, Doctoral Degree, using 1, 2, 3, respectively. Students who indicated Associates degree, Professional degree, Uncertain, or Other were excluded from data analysis.

What is the highest degree you plan to attain?

- ○ Associate's degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ Doctoral degree
- ○ Professional degree (MD, JD, DDS, Ed.D, etc)
- ○ Uncertain
- ○ Other, please specify _____

Interest in getting a job in computing research at a college/university (RQ1): Likert-type scale variable measuring students' level of interest in getting a job as a college/university professor.

How interested are you in having a computing job like the one listed below after you finish your highest degree?

- College/University professor in computing field

Very disinterested (1)	Somewhat disinterested (2)	Neither disinterested not interested (3)	Somewhat interested (4)	Very Interested (5)

Interest in getting a job in computing research in industry/ government lab (RQ1): Likert-type scale variable measuring students' level of interest in getting a job in computing research in industry/ government lab.

How interested are you in having a computing job like the one listed below after you finish your highest degree?

- Computing researcher in industry or government lab

Very disinterested (1)	Somewhat disinterested (2)	Neither disinterested not interested (3)	Somewhat interested (4)	Very Interested (5)

Intentions of getting a job in computing research (RQ2): Likert-type scale variable measuring the likelihood of getting a job in computing research after having completed a SURE.

How much did your your REU experience influence the likelihood that you will accomplish the following?

- Get a job in computing research

Much less likely (1)	Somewhat less likely (2)	Unchanged (3)	Somewhat more likely (4)	Much more likely (5)

Predictor variables

SURE participation (RQ1): Dichotomous indicator of whether student participated in a SURE program or not. Only those URE programs that took place over the summer were evaluated. Non-SURE participation was coded as 0; SURE participation was coded as 1.

Since September 2013, have you participated in any of the following research activities? Please select all that apply. (* URE included in the current research; ** option selected by SURE non-participants)

- ○ *Undergraduate research experience at my home institution
- ○ *Undergraduate research experience at another institution
- ○ *Research internship in an industry or government lab
- ○ Research course
- ○ Independent study
- ○ Thesis project
- ○ **None of the above

When did your REU experience take place? (* selected by SURE participants)

- ○ *Summer
- ○ School year
- ○ Winter break/semester

SURE characteristics (RQ2): The following 9 variables measure a variety of characteristics of SURE programs based on students' responses to the level of experience gained, amount of knowledge acquired, or extent of exposure ranked on a 5 point Likert-type scale. While some of the characteristics were measured using a single survey item, other characteristics were created by averaging across multiple items. Survey items for each SURE characteristic variable and reliability statistics, when appropriate, are listed below.

Collaboration with others. (Variable name: Collaboration)
(2 items, Cronbach's alpha = 0.86)

How much experience did you gain in the following activities?

- Collaborating with colleagues

None (1)	A Little (2)	Some (3)	A Good Amount (4)	A Lot (5)

How much knowledge have you gained in the following areas as a result of your research experience?

- How to work collaboratively with others

None (1)	A Little (2)	Some (3)	A Good Amount (4)	A Lot (5)

Information on how computing can make a positive contribution to society. Variable name: Social Impact

How much knowledge have you gained in the following areas as a result of your research experience?

- How computing can make a positive contribution to society

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Exposure to computing career options. Variable name: Career Options

How much knowledge have you gained in the following areas as a result of your research experience?

- What career options are available within computing

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Exposure to research skills. Variable name: Research Skills

(5 items, Cronbach's alpha = 0.87)

How much experience did you gain in the following activities?

- Using scientific methods to test a hypothesis
- Generating hypotheses
- Collecting data or conducting experiments
- Analyzing data with statistics or other tools
- Explaining results

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Learning how to working independently. Variable name: Independence

How much knowledge have you gained in the following areas as a result of your research experience?

- How to work independently

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Exposure to the research dissemination process. Variable name: Research Dissemination

(4 items, Cronbach's alpha = 0.86)

How much experience did you gain in the following activities?

- Summarizing published research results
- Writing or co-authoring a research paper or report
- Presenting a research paper or report
- Publishing a research paper or report

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Involvement in the design of a research project. Variable name: Research Involvement
(3 items, Cronbach's alpha = 0.83)

How much experience did you gain in the following activities?

- The design of the research project(s)
- What research techniques/materials were used
- Deciding what to do next (e.g. follow-up studies)

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Learning about the graduate admission process. Variable name: Admissions
(2 items, Cronbach's alpha = 0.94)

How much knowledge have you gained in the following areas as a result of your research experience?

- Criteria for admission to graduate programs
- How to select the right graduate program for you

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Learning about graduate student life. Variable name: Graduate Student

How much knowledge have you gained in the following areas as a result of your research experience?

- What it is like to be a graduate student in computer science or computer engineering

None (1) A Little (2) Some (3) A Good Amount (4) A Lot (5)

Moderator

Demographic Group: Dichotomous indicator for underrepresented students (URMW) versus majority male students (MM). URMW students included men who indicated their race/ethnicity was Black/African American, Hispanic/Latino, Native American, or Hawaiian/Pacific Islander, and all women. Note that our sample did not contain any Native American, or Hawaiian/Pacific Islander men. MM students included men who indicated Asian/Asian American and White/Caucasian or European American race/ethnicity. MM students were coded as 0; URMW students were coded as 1. Students who indicated "Other" for gender, and/or Arab/Middle Eastern/Persian, "Other", or selected more than one race/ethnicity were not included in our analyses.

Please indicate your gender.

- ○ Female
- ○ Male
- ○ Other; please specify _____

What is your race/ethnicity? Please select all that apply.

- ○ Asian or Asian American
- ○ Black, African American
- ○ Native American
- ○ Native Hawaiian or Other Pacific Islander
- ○ White, Caucasian or European American
- ○ Hispanic or Latina/o
- ○ Arab, Middle Eastern, or Persian
- ○ Other; please specify _____

Covariates

First-Generation status: Students indicated parented education level for up to two parents. Students with at least one parent with "some college or an Associate's degree" were coded as non-first-generation students. All other students were coded as first generation students. "Other" was coded as missing data. Non-first-generation students were coded as 0; first-generation students were coded as 1.

What is the highest level of education attained by one of your parents/guardians?

- ○ Less than high school
- ○ High school graduate or GED
- ○ Some college or Associate's degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ PhD
- ○ Professional degree (MD, JD, Ed.D, etc.)
- ○ Other; please specify _____

What is the highest level of education attained by your SECOND parent/guardian?

- ○ Less than high school
- ○ High school graduate or GED
- ○ Some college or Associate's degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ PhD
- ○ Professional degree (MD, JD, Ed.D, etc.)
- ○ Other; please specify _____

Class standing: Ordinal variable indicating the class standing of students at the time of survey. This variable includes first year, second year, third year, fourth year and fifth year students, using coding 1-5.

Department type: We conducted a content analysis of students' home institutions' computing degree program websites in order to group students' department type by the highest degree granted in their department. Department type was coded into three categories, based on the highest degree awarded in student's home computing department: B.S., M.S., or Ph.D. This variable was coded as an ordinal measure ranging between 1 and 3. (1: B.S., 2: M.S., 3: Ph.D.)

Major grade point average: Continuous variable measuring students' grade point average (GPA) in their majors. Possible values are bound between 0-4.

Descriptive Statistics

Table 1. Descriptive statistics for RQ1 sample of SURE and Non-SURE participants (n = 202)

Model component	Variable name	Descriptive Statistics		
Predictors	SURE Participation	SURE		50%
		Non- SURE		50%
Moderator	Demographic group	URMW		49%
		MM		51%
Covariates	Class standing	First Year		4%
		Second Year		16%
		Third Year		34%
		Fourth Year		34%
		Fifth Year		12%
	Major GPA	Mean	Median	SD
		3.62	3.7	0.38
	Department type	B.S.		34%
		M.S.		5%
		PhD		61%
	First-generation status	First-Gen		4%
		Non-First-Gen		96%

Table 2a. Descriptive statistics for the RQ1 outcome variables for URMW and MM students separately: Non-SURE participants (n = 101)

Outcome	Moderator					
	URMW n = 47			MM n = 54		
Post-secondary academic intentions	B.S.		38%	B.S.		69%
	M.S.		47%	M.S.		26%
	PhD		15%	PhD		6%
Interest in getting a job as a college/university professor in computing *(1) Very disinterested to (5) Very interested*	Mean	Median	SD	Mean	Median	SD
	2.74	3.00	1.50	2.67	2.50	1.41
Interest in getting a job in computing research in industry/ government lab *(1) Very disinterested to (5) Very interested*	Mean	Median	SD	Mean	Median	SD
	3.08	3.00	1.47	3.19	3.00	1.24

Table 2b. Descriptive statistics for the RQ1 outcome variables for URMW and MM students separately: SURE participants (n = 101)

Outcome	Moderator					
	URMW n = 52			MM n = 49		
Post-secondary academic intentions	B.S.		25%	B.S.		30%
	M.S.		33%	M.S.		33%
	PhD		42%	PhD		37%
Interest in getting a job as a college/university professor in computing *(1) Very disinterested to (5) Very interested*	Mean	Median	SD	Mean	Median	SD
	2.94	3.00	1.50	3.15	3.00	1.31
Interest in getting a job in computing research in industry/ government lab *(1) Very disinterested to (5) Very interested*	Mean	Median	SD	Mean	Median	SD
	3.77	4.00	1.17	3.78	4.00	1.05

Table 3. Descriptive statistics for RQ2 sample of SURE participants (n = 101)

Model component	Variable name	Descriptive Statistics		
Predictor	Level of exposure to SURE Characteristics *(1) None to (5) A Lot*	Mean	Median	SD
	Collaboration	3.84	4.00	1.15
	Social Impact	3.67	4.00	1.32
	Career Options	3.23	3.00	1.36
	Research Skills	3.20	3.40	1.11
	Working Independently	4.03	4.00	1.01
	Research Dissemination	2.62	2.50	1.25
	Research Involvement	3.35	3.33	1.17
	Admissions	3.03	3.00	1.43
	Graduate Student	3.39	4.00	1.34
Moderator	Demographic group	URMW		51%
		MM		49%
Covariates	Class standing	First Year		4%
		Second Year		15%
		Third Year		36%
		Fourth Year		33%
		Fifth Year		12%
	Major GPA	Mean	Median	SD
		3.62	3.7	0.37
	Department type	B.S.		35%
		M.S.		3%
		PhD		62%
	First-generation status	First-Gen		4%
		Non-First-Gen		96%

Table 4. Descriptive statistics for the RQ2 outcome variables for URMW and MM students separately (n = 101)

Outcome	Moderator					
	URMW n = 52			MM n = 49		
Post-secondary academic intentions	B.S.		25%	B.S.		30%
	M.S.		33%	M.S.		33%
	PhD		42%	PhD		37%
Influence of SURE on intentions for getting a computing research job *(1) Much less likely to (5) Much more likely*	Mean	Median	SD	Mean	Median	SD
	3.88	4.00	1.13	3.45	3.00	1.00

Models

The analyses in this report focus on two main research questions explaining two outcomes of interest: (1) students' post-secondary academic intentions, and (2) students' interest in pursuing a career in computing research. Response options for our two outcomes used different measurement techniques: multi-level categorical versus Likert-style. As a result, we employed two different modeling strategies to estimate the relationship between the outcome variables and the predictor and moderator variables, which we describe below.

For students' degree plans, we use a multinomial logistic regression, and treated response options as an unordered categorical variable with more than two values. Specifically, this variable contained three levels indicating students' highest degree intentions from the following list: Bachelor's degree, Master's degree, and Doctoral degree.

The multinomial logistic regression models estimate the probability of each category of the dependent variable occurring compared to a base category. In the case of our analysis, we compare the probability of a student wanting to pursue a Ph.D. versus a B.S. or an M.S. (i.e., the Ph.D. category is our base category). This allows us to examine the factors that influence students' desire to attain post-graduate degrees in computing related fields.

Models looking at the students' interest in getting a job in computing research using Likert-style scale items are estimated using ordinary least squares (OLS) method. These models estimate the linear relationship between the predictor and moderator variables and the outcome by minimizing the distance between the actual and predicted values of the outcome variable. The coefficient estimates yielded from these models give us the direction and magnitude of change we expect in the outcome variable based on one unit change in the respective predictor variable.

Each model contained a predictor (RQ1: SURE participation; RQ2: SURE characteristic), moderator (Demographic Group) and covariates (Class standing; Major GPA; Department type; First-generation status). While the predictor differed depending on our research question, the moderator and covariates remained constant across all models. In all of our models, we also included a multiplicative interaction term between the predictor variable and the moderator variable. This term is computed and entered into the regression equations, given our research questions concerning the moderating role of demographic group on the relationship between each predictor and outcome variables.

Results

We first look at the influence of SURE participation and demographic group on students' post-secondary academic intentions, then on the students' interest in getting a job in computing research (within academia or industry/government). Then, we turn to the impact of each SURE characteristic on students' post-secondary academic intentions and interest in getting a job in computing research.

We do not present regression output for our full models, given the conditional nature of our output (i.e., interpretation of the interaction term in our models is contingent on our dummy coding scheme for Demographic group, such that output for the Predictor variable is only relevant to students who were coded as 0)[5]. Instead, and consistent with our presentation style in the main text, we only present output for simple effects of our main predictor and moderator variables. The simple effects show the effect of a change in the predictor on the outcome for given values of the moderator variable.

In the case of SURE participation, the simple effects tables show the effect of participating in a SURE program (i.e. changing SURE participation variable from 0 to 1) for URMW students (i.e. URMW = 1) and MM students (i.e. URMW = 0) on each outcome. For instance, the results in **Table 5** show that URMW students have a 40% lower probability of pursuing a B.S. compared to a Ph.D. and 35% lower probability of pursuing an M.S. compared to a Ph.D. if they participated in a SURE. Note that these comparisons are reversible. That is, having a lower probability of pursuing a B.S. or M.S. degree compared to a Ph.D. translates to having a higher probability of pursuing a Ph.D. compared to a B.S. or an M.S.

In the case of SURE characteristic variables, the average simple effects illustrate the effect of moving from the minimum value of the Likert-type scale (i.e. exposure to SURE characteristic = 1) to the maximum value of the scale (i.e. exposure to SURE characteristic = 5) for URMW and MM students. As an example, we can look at the results in **Table 7**. This simple effects table shows that URMW students who learned a high degree of research skills are 82% less likely to plan to pursue a B.S. instead of a PhD compared to students who learned a low degree of research skills.

[5] Full regression output is available upon request: contact cerp@cra.org.

Table 5. Simple effects of SURE Participation on Post-secondary Academic Intentions for URMW and MM Students

Highest Intended Degree	URMW Students			MM Students		
	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound
B.S.	-0.40*	-0.62	-0.16	-0.46*	-0.67	-0.26
M.S.	-0.35*	-0.55	-0.12	-0.33*	-0.56	-0.07

Note. Simple effects calculated from a multinomial logistic regression model with the base category set as Ph.D. * $p < .05$.

Table 6. Simple effects of SURE Participation on Interest in Getting a Job as a College/University Professor and as a Computing Researcher in an Industry/Government Lab for URMW and MM Students

Career Track	URMW Students			MM Students		
	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound
Academia	0.23	-0.33	0.79	0.46	-0.10	1.01
Industry/ Gov. Lab	0.68*	0.19	1.17	0.60*	0.12	1.08

Note. Simple effects calculated from an OLS regression model. * $p < .05$.

Table 7. Simple Effects of SURE Characteristics on Post-secondary Academic Intentions for URMW and MM Students

	URMW Students			MM Students		
	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound
	Collaboration			Collaboration		
B.S.	-0.56	-0.88	0.02	0.20	-0.49	0.70
M.S.	-0.44	-0.81	0.14	-0.43	-0.80	0.12
	Social Impact			Social Impact		
B.S.	-0.49	-0.84	0.06	0.11	-0.40	0.60
M.S.	-0.32	-0.73	0.23	-0.06	-0.55	0.43
	Career Options			Career Options		
B.S.	-0.49	-0.83	0.00	0.46	-0.11	0.83
M.S.	-0.38	-0.75	0.10	0.06	-0.48	0.57
	Research Skills			Research Skills		
B.S.	-0.82*	-0.97	-0.47	0.10	-0.54	0.70
M.S.	-0.52	-0.87	0.00	-0.23	-0.75	0.42
	Working Independently			Working Independently		
B.S.	-0.42	-0.82	0.20	0.24	-0.37	0.72
M.S.	0.18	-0.46	0.63	0.09	-0.47	0.62
	Research Dissemination			Research Dissemination		
B.S.	-0.65*	-0.91	-0.23	-0.30	-0.75	0.31
M.S.	-0.28	-0.70	0.23	-0.19	-0.68	0.37
	Research Involvement			Research Involvement		
B.S.	-0.49	-0.83	0.03	-0.66*	-0.94	-0.02
M.S.	-0.11	-0.61	0.35	-0.92*	-0.99	-0.66
	Admissions			Admissions		
B.S.	-0.75*	-0.95	-0.38	-0.40	-0.78	0.12
M.S.	-0.54*	-0.85	-0.11	-0.50	-0.84	0.01
	Graduate Student			Graduate Student		
B.S.	-0.65*	-0.91	-0.20	0.10	-0.50	0.65
M.S.	-0.40	-0.75	0.10	-0.44	-0.81	0.10

Note. Simple effects calculated from a multinomial logistic regression model with the base category set as Ph.D.* $p < .05$.

Table 8. Simple effects of SURE characteristics on Intentions to Get a Job in Computing Research for URMW and MM Students

URMW Students			MM Students		
Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound	Average Simple Effect	95% CI Lower Bound	95% CI Upper Bound
Collaboration			Collaboration		
0.70*	0.50	0.90	-0.01	-0.24	0.23
Social Impact			Social Impact		
0.59*	0.38	0.80	0.12	-0.09	0.34
Career Options			Career Options		
0.48*	0.28	0.67	0.05	-0.17	0.27
Research Skills			Research Skills		
0.59*	0.37	0.81	0.10	-0.17	0.37
Working Independently			Working Independently		
0.46*	0.18	0.73	-0.10	-0.39	0.20
Research Dissemination			Research Dissemination		
0.42*	0.21	0.63	0.18	-0.06	0.43
Research Involvement			Research Involvement		
0.60*	0.40	0.80	0.22	-0.04	0.48
Admissions			Admissions		
0.44*	0.25	0.62	0.12	-0.09	0.33
Graduate Student			Graduate Student		
0.38*	0.18	0.59	0.14	-0.10	0.37

Note. Simple effects calculated from an OLS regression model. * $p < .05$.