What Black Undergraduates Majoring in STEM Learn from Structured Research Programs: Differences by Sex

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Abstract

Colleges and universities have invested in structured undergraduate research experiences (SUREs) as a mechanism for broadening participation among underrepresented racial/ethnic minorities (URMs), yet few studies focus on sex differences in the perceived benefits that URMs gain from their participation in SUREs. Using survey data from 54 African American SURE participants at 3 major research universities, results suggest: (a) women reported higher learning gains on 8 outcomes including research self-efficacy and (b) one statistically significant sex-based difference in terms of learning about the research/scientific process, $F(1,52)=2.29$, $p<0.10$. Hierarchical linear regression tests indicate that perceived learning gains mediate the relationship between sex and Black students' subjective evaluation of the program, $F(13,39)=3.40$, $p<0.01$, thereby reducing the "sex effect" to non-significance. In other words, differences in Black students' satisfaction with the program are explained, in part, by differences in perceived learning gains not gender. Implications for policy, practice, and research are highlighted.

Introduction

Achievement disparities between White and Black students have been well-documented, although they remain wide and persistent.1 For instance, African Americans, on average, perform at the same level as White students in the lowest quartile of achievement, especially in math and science. Similar results are found at the postsecondary level where White students represent 65% of bachelor's (BA) degrees in science, technology, engineering, and math (STEM) fields, whereas only 8% are earned by African Americans.2

Even larger gaps are observed between African American men and women in terms of national postsecondary enrollment and attainment trends. For instance, Black women outnumber their same-race male counterparts by a ratio of 2:1 and more than two-thirds of Black men who enter college do not graduate within 6 years, the lowest completion rate among both sexes and all ethnic groups.3 To reduce, if not eliminate, these gaps, as well as to broaden participation among underrepresented minorities (URMs), colleges and universities have invested in structured undergraduate research experiences (SUREs), which provide opportunities for students to engage in research with a scientist or engineer. SUREs are designed generally to nurture students' interest in STEM, improve research skills, enhance research self-efficacy, and facilitate entry into graduate school, yet few studies focus on (a) the gains (i.e., knowledge, competencies, skills) that students acquire through their involvement in SUREs or (b) sex differences in the perceived benefits that Black students report.4 This is the gap addressed by the study upon which this report is based.

The purpose of the study was to measure the perceived learning gains that accrue to African American undergraduates who participate in SUREs at predominantly White institutions. Secondly, the study aimed to measure differences between Black men's and women's perceived gains as a result of their participation. Lastly, we sought to determine if learning mediated the relationship between sex and students' subjective evaluation (i.e., satisfaction) of their experience.

Literature Review

Undergraduates in STEM majors have been studied extensively to understand what leads students to choose a science or science-related major, persist to graduation in such fields, and ultimately choose a science or technical career.5,6 Surprisingly, Seymour and Hewitt found that approximately 50% of undergraduates that select science majors upon entry to college, change to a non-science major before graduation.7 Evidence also indicates that the proportion of Black students who earn degrees in STEM (8%) pales in comparison to White and Asian counterparts (65%).8 That science and STEM-related careers are perceived as isolating, highly competitive, impersonal, and time-consuming exacerbates the problem of attracting students to science majors;9,10 especially URMs such as African Americans who tend to operate collaboratively, more "as a family," and express strong desires to use their college education in service to their community and members of their race.11,12 A growing number of studies have shown that SUREs, however, increase students' increase in STEM, mitigate a few of the challenges that STEM majors face, and assist in their retention to graduation.13,14

Research on SUREs can be organized into two categories: studies that describe the general nature and characteristics of SUREs and empirical studies that measure the benefits SURE students derive from their experiences. For instance, working with a faculty mentor on a research project during the summer, choosing or becoming familiar with the study's particular focus, reviewing the existing literature about a topic, learning statistics, and writing a formal, albeit usually brief, research paper are key components of SUREs.15 Some students also engage in actual data collection (via surveys or interviews), data analysis, or dissemination (via a professional conference or publication) during their experience.16

Scholars have only just begun to conduct studies to identify an empirically-based set of benefits that accrue to students who participate in SUREs.17,18,19 For instance, Lopatto analyzed survey data from 1,135 undergraduate participants at 41 institutions to determine whether undergraduate research experiences enhanced the educational experience of science majors. Over 83% of the respondents indicated plans or continuing plans to pursue post-graduate education in the sciences. And, participants did not differ significantly in terms of sex or race on future career plans, reported levels of benefits, or plans to pursue graduate education. Other studies show that SUREs nurture students' interest in science careers by acclimating them to scientific culture,20,21 including understanding the research process and observing the multiple responsibilities of faculty members.22,23,24 The weight of evidence also suggests that SUREs and mentoring aid in the retention of students,25 including African Americans,26 facilitate purposeful engagement among students and faculty members,27 and promote students' confidence in their ability to pursue graduate education and to conduct empirical research.20,28

Despite existing research on the role that SUREs play in enhancing the collegiate experiences of students in general and African Americans in particular, few contemporary studies examine what Black undergraduates at predominantly White institutions learn from structured UREs and whether such experiences promote their research self-efficacy, which has been linked to their decision to pursue and persist in a STEM major.12 Secondly, much of the existing literature on UREs fails to focus on URMs specifically and does not consider whether UREs benefit URM men and women differently. And although a good deal is known about how Black men and women experience college differently, extant research on SUREs offers very little insight into sex differences in the gains that accrue from such participation. Indeed, more research is needed to provide educators with information they can use to make sound decisions about student recruitment, admission, and program implementation. The present study was designed to fill this gap in the literature.

Method

As part of a larger study, Investigating the Critical Junctures: Strategies that Broaden Minority Participation in STEM Fields, funded by the National Science Foundation, this statistical analysis is based on results from the Year 1 SURE Survey only.

Sample

The sample consisted of 54 African American undergraduates who participated in a SURE during the summer 2008 semester at one of three major research-extensive universities; two public universities located in the southeast region of the country and one private university on the Pacific coast. A large majority (94%) of participants were upperclassmen (i.e., juniors, seniors), 96% indicated plans to pursue a graduate degree, 65% were women, and 35% were UG STEM majors, as defined by the NSF, while 35% were majoring in social sciences (e.g., psychology, sociology). The mean age was 22.31 (SD=4.96; range: 19-43 years) and the mean level of satisfaction with the program was 5.93 (SD=1.13; range: 2-7). Although all students in our analysis were African American, 70% of participants worked with White faculty mentors, 21% with African American faculty, and 9% with Asian faculty; slightly more SURE participants work with male faculty (55%) than women faculty. Table 1 summarizes characteristics of the study's sample.

Table 1: Description of the Sample

Variable	**M (SD)/%**
Students' sex	
Male	35
Female	65
UG Major	
STEM	35
Social sciences	35
Other	30
Race of mentor	
White	68
Black	21
Asian	9
Other	2
Sex of mentor	
Male	55
Female	45
Aspire to graduate degree?	
Yes	96
No	4
Age	22.31 (4.96)
Satisfaction with SURE	5.93 (1.13)

Note. M=mean. SD=standard deviation. UG=undergraduate. STEM=science, technology, engineering, math. SURE=structured undergraduate research experience.

Data Collection

Data were collected during the summer 2008 term using a web-based survey, with the exception of one program whose director preferred paper surveys. Participants responded to the Survey of Summer Research Programs (SSRP), a 33-item instrument developed by the principal investigator for the purposes of the study. One subscale (3 items, research self-efficacy) assessed students' confidence in their ability to conduct research. Students responded on a scale ranging from 1 (no confidence at all) to 7 (complete confidence). The reliability coefficient for this subscale for the study sample was 0.80.

Independent variables included age (in years), sex (0=male, 1=female), year in college (0=freshman/sophomore, 1=junior/senior), and 9 items measured students' perceived learning gains in areas addressed by the program (e.g., statistics, scientific writing, ethical conduct in research). Each of the learning outcome items were placed on a 7-point

scale ranging from 1 (not at all) to 7 (very much); a sample item asked, "Thinking about your SURE, how much have you learned about [careers in research in science]." Another item asked students to rate the extent to which SURE participation affected their graduate school aspirations; response options ranged from 1 (still have no plans) to 3 (sustained or increased interest).

Data Analysis

Data analysis proceeded in three stages. First, data were prepared for analysis using a combination of data cleaning and recoding techniques. Summated scales (e.g., research self-efficacy) were created by testing the underlying structure of items using factor analysis, calculating the internal reliability of individual items using alpha coefficients, and summing together items, that according to research and statistical tests, were related. Descriptive statistics were calculated for the learning outcomes items and analyses of variance (ANOVA) were conducted to test for differences by sex. Finally, hierarchical linear regression tests were conducted to measure the influence of sex on satisfaction, controlling for differences in perceived learning gains.

Results

Descriptive statistics indicate that African American undergraduates benefit from their involvement in SUREs. Women report higher perceived gains on 8 outcomes including self-efficacy as shown in Table 2; only one (*) was statistically significant, $F(1,52)=2.29$, $p<0.10$.

Table 2: Descriptive Statistics of Perceived Learning Gains by Sex

	Men + Women	**Men**	**Women**
Learning Outcome	**M(SD)**	**M(SD)**	**M(SD)**
Affect on graduate aspirations	2.78(0.50)	2.84(0.38)	2.74(0.56)
Research/scientific process*	5.89(1.31)	5.53(1.07)	6.09(1.40)
Life as faculty/researcher	5.72(1.45)	5.58(1.39)	5.80(1.49)
Statistics/quantitative analysis	5.56(1.62)	5.58(1.35)	5.54(1.77)
Qualitative data analysis	5.63(1.51)	5.53(1.61)	5.69(1.47)
Working independently	5.93(1.47)	5.68(1.60)	6.06(1.39)
Careers in research/science	5.80(1.41)	5.63(1.26)	5.89(1.49)
Scientific writing	5.46(1.34)	5.42(1.26)	5.49(1.40)
Ethical conduct in research	5.39(1.39)	5.42(1.31)	5.37(1.46)
Presenting research publicly	6.19(1.20)	6.00(1.20)	6.29(1.20)
Research self-efficacy	12.94(1.85)	12.84(1.86)	13.00(1.87)

Hierarchical linear regression techniques were employed to examine the relationship between students' sex and their subjective evaluation of their experience, controlling for differences in perceived learning gains, based on theoretical support that students who gain more from their investment in SUREs may also feel better about their experience. Hierarchical linear regression tests indicate that perceived learning gains mediate the relationship between sex and Black students' satisfaction with their experience, $F(13,39)=3.40$, $p<0.01$, $R=0.73$, $R2=0.53$, Adjusted $R2=0.38$. Sequential regression models indicate that the "sex effect" on satisfaction was reduced from 0.21 to 0.17 by controlling for differences in self-reported learning gains, although sex was statistically non-significant in the final model. In other words, variability in Black students' satisfaction with the SURE is explained, in part, by differences in perceived learning gains, not participants' sex. Table 3 presents a summary of the regression analysis.

Table 3: Sex Regressed on Satisfaction, Controlling for Differences in Learning Gains

Variable	B	SE	_
Constant	4.05	1.88	
Age	0.03	0.03	0.12
Year in school	- 0.65	0.59	- 0.14
RSP	- 0.25	0.16	- 0.29
BRF**	0.46	0.19	0.59
SQA	0.08	0.12	0.11
QDA	0.12	0.11	0.16
LWI**	- 0.20	0.10	- 0.26
CRS	0.18	0.15	0.23
SW	- 0.15	0.14	- 0.17
ECR	- 0.05	0.13	- 0.07
PRF	- 0.06	0.16	- 0.06
RSE	0.11	0.10	0.18
Sex	0.17	0.28	0.07

Note. RSP=research/scientific process. BRF=being research/faculty. SQA=statistics/quantitative analysis. QDA=qualitative data analysis. LWI=learning to work independently. CRS=careers in research/science. SW=scientific writing. ECR=ethical conduct in research. PRF=presenting research findings. RSE=research self-efficacy. R=0.73, R2=0.53, Adjusted R2=0.38. F(13,39)=3.40, p<0.01.

Discussion

The purpose of the study was to measure the perceived learning gains that accrue to African American undergraduates who participate in SUREs at predominantly White institutions. Also, the study aimed to measure differences between Black men and women in the perceived gains reported as a result of their participation, as well as to determine if learning mediated the relationship between sex and students' subjective evaluation (i.e., satisfaction) of their experience. Statistical results suggest several major conclusions that will be discussed in light of the existing research. Then, we highlight implications for policy, practice, and future research before mentioning a few limitations of the present study.

It is clear that Black students feel as if they learn a good deal from their participation in SUREs based on the fact that students reported gains in all areas. These findings are consistent with prior research about the efficacy of SUREs. Interestingly, however, Black students reported higher gains in learning about the research/scientific process than ethical conduct. This is worth noting given recent national debates about the importance of ethical conduct in science and social responsibility in areas of research and development.29 For instance, ethical principles that guide individual behaviors and value systems that determine moral judgments are central to debates about the human genome project, genetics, euthanasia, and even educational policy. Therefore, it seems critical to match teaching about the scientific/research process with teaching about ethical conduct and the proper use of science in society. As Albert Einstein warned, "Technological [scientific] progress is like an axe in the hands of a pathological criminal." Learned minds must also be conditioned to acceptable standards of behavior recognizing that science/research can be used to discover or destroy. Echoing Rene Descartes, we remind educators of his wisdom: "The greatest minds are capable of the greatest vices as well as of the greatest virtues."

Another finding that warrants discussion suggests that SUREs affect Black students' graduate degree aspirations, similar to what has been found in previous studies. Our report, however, suggests that SURE participation tends to sustain Black students' pre-existing aspirations to attend graduate school rather than stimulate or increase degree aspirations. This is an important nuance in our understanding of the role that SUREs play in preparing undergraduates for post-BA studies in STEM fields. SUREs may be most effective in nurturing or sustaining interest among Black

students who are already predisposed to earning a graduate degree but may have little to no effect on those who have lower degree aspirations. One possible explanation is that SUREs offer students inclined to attend graduate school an opportunity to apply theory (i.e., what they've learned) to practice (i.e., engaging in research with faculty) thereby reifying their interest in science, understanding of the research process, and identity as a scholar/researcher.

Hurtado et al. (2009) found that although students expressed interest in science prior to entering college, few were knowledgeable about science-related career options. Students in our study reported gains in learning about science careers through participation in SUREs, demonstrating another benefit that accrues to Black men and women who participate in such programs. Having a limited understanding of STEM career opportunities may be one rationale for the low representation of Black students in such fields. By participating in SUREs, Black students are exposed to various STEM careers and, as a result, may be more likely to enter the field upon graduation from college.

Not only did Black students report learning gains overall, but also Black women who participated in SUREs tended to report higher gains than men in 8 learning outcomes. For example, women reported modestly higher gains than men in "[learning about] presenting research publicly." As another example, the highest learning gain reported by women (i.e., research/scientific process) was one of the lowest reported by men. Findings suggest that there are observable sex differences in the gains reported by Black men and women who participate in SUREs, although none of these differences were statistically significant when examined using multivariate statistics.

Similar to previous research on Black undergraduates engagement with faculty members (Strayhorn & Terrell, 2007), we found no sex differences in learning outcomes among Black undergraduates in SUREs. Findings suggest that Black men and women benefit almost equally from participation in SUREs. However, we found that learning mediates the relationship between sex and students' subjective evaluations of their SURE program. In other words, Black students who learn more tend to be more satisfied with their experience, while those who learn less report lower satisfaction. And it's learning, not gender, that explains variability in Black undergraduates' satisfaction with their SURE experience. As one of very few studies that examine the influence of learning on satisfaction, the present study breaks new ground on what's known about SUREs and offers a number of implications for future policy, practice, and research.

Since part of the goal in educational research is to describe how a constellation of individual and program-level conditions work together in different college settings to promote student engagement and success, the present study makes a significant contribution to the literature as it points to the role that demographic (e.g., sex) and programmatic (e.g., learning outcomes) characteristics play in determining Black students' satisfaction with SUREs. Program coordinators, undergraduate deans, and student affairs administrators who work in/with SUREs might call upon these findings when designing new or revising existing programs. By creating more learning opportunities (e.g., expanding training on ethical conduct), administrators can increase student learning and, subsequently, enhance student satisfaction.

Despite its worthwhile contributions, the study has several limitations. First, the sample is quite small and this diminishes the power of our statistical tests and any conclusions based on such analyses. While secondary databases may provide larger samples of undergraduates who worked with faculty on research (see Strayhorn & Terrell, 2007), they do not provide information about the learning and general outcomes that accrue to individuals as a result of their SURE participation. This is a unique feature of the survey upon which our study was based.

Second, the sample was drawn from three large research-extensive universities. Findings from this report are likely to relate to institutions of similar size and classification, but may offer little insight into SURE programs at small liberal arts or teaching colleges. Future research might address this limitation by studying the experiences of Black undergraduates in SUREs at such institutions. While important to discuss, these concerns do not limit the importance of the present study and its contribution to the extant literature on SUREs.

Acknowledgements

This research was supported by a grant from the National Science Foundation (Grant EHR #0747304). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agency.

References

01. Chubb, J. E., & Loveless, T. (2002). Bridging the achievement gap. In J. E. Chubb & T. Loveless (Eds.), Bridging the achievement gap (pp. 1-10). Washington, DC: Brookings Institution Press.
02. National Science Board. (2006). Science and engineering indicators 2006 (Two volumes). Arlington, VA: National Science Foundation.
03. Strayhorn, T. L. (2008). Fittin' In: Do diverse interactions with peers affect sense of belonging for Black men at predominantly White institutions? The NASPA Journal, 45(4), 501-527.
04. Hu, S., Kuh, G. D., & Gayles, J. G. (2007). Engaging undergraduate students in research activities: Are research universities doing a better job? Innovative Higher Education, 32, 167-177.
05. Maton, K. I., Hrabowski III, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. Journal of Research in Science Teaching, 37(7), 629-654.
06. Villarejo, M., Barlow, A. E. I., Kogan, D., Veazey, B. D., & Sweeney, J. K. (2008). Encouraging minority undergraduates to choose science careers: Career paths survey results. Life Sciences Education, 7, 394-409.
07. Seymour, E., & Hewitt, N. (1997). Talking about leaving. Boulder, CO: Westview Press.
08. National Science Board. (2006). Science and engineering indicators 2006 (Two volumes). Arlington, VA: National Science Foundation.
09. Packard, B. W. (2005). Mentoring and retention in college science: Reflections on the sophomore year. Journal of College Student Retention, 6(3), 289-300.
10. Johnson, A. C. (2007). Unintended consequences: How science professors discourage women of color. Science Education. Wiley Periodicals, Inc.
11. Hirt, J. B., Strayhorn, T. L., Amelink, C. T., & Bennett, B. R. (2006). The nature of student affairs work at historically Black colleges and universities. Journal of College Student Development, 47(6), 661-676.
12. Seymour, E. (1992, February). "The Problem Iceberg" in science, mathematics, and engineering education: Student explanations for high attrition rates. Journal of College Science Teaching, 230-238.
13. Hurtado, S., Cabrera, N., Lin, M. H., Arrellano, L., & Espinosa, L. L. (2009). Diversifying science: Underrepresented student experiences in structured research programs. Research in Higher Education, 50, 189-214.
14. Hu, S., Scheuch, K., Schwartz, R., Gaston Gayles, J, & Li, S. (2008). Reinventing undergraduate education: Engaging college students in research and creative activities. ASHE Higher Education Report, 33(4).
15. Hu, S., Scheuch, K., Schwartz, R., Gaston Gayles, J, & Li, S. (2008). Reinventing undergraduate education: Engaging college students in research and creative activities. ASHE Higher Education Report, 33(4).
16. Strayhorn, T. L. (2009, April). Unraveling the benefits of summer research experiences for economically disadvantaged ethnic minorities: A mixed methods study. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.
17. Lopatto, D. (2003). The essential features of undergraduate research. Council of Undergraduate Research Quarterly, 24, 139-142.
18. Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. Cell Biology Education, 3(4), 270-277.
19. Seymour, R. Hunter, A. B., Laursen, S., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates: First findings from a three-year study. Science Education, 88, 493-594.
20. Hurtado, S., Cabrera, N., Lin, M. H., Arrellano, L., & Espinosa, L. L. (2009). Diversifying science: Underrepresented student experiences in structured research programs. Research in Higher Education, 50, 189-214.
21. Hu, S., Scheuch, K., Schwartz, R., Gaston Gayles, J, & Li, S. (2008). Reinventing undergraduate education: Engaging college students in research and creative activities. ASHE Higher Education Report, 33(4).

22. Maton, K. I., Hrabowski III, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. Journal of Research in Science Teaching, 37(7), 629-654.
23. Seymour, E., & Hewitt, N. (1997). Talking about leaving. Boulder, CO: Westview Press.
24. Kahveci, A., Southerland, S. A., & Gilmer, P. (2006). Retaining undergraduate women in science, mathematics, and engineering. Journal of College Science Teaching, 36(3), 34-38.
25. Kuh, G. D. (1995). The other curriculum: Out-of-class experiences associated with student learning and personal development. Journal of Higher Education, 66, 123-155.
26. Strayhorn, T. L., & Terrell, M. C. (2007). Mentoring and satisfaction with college for Black students. The Negro Educational Review, 58(1-2), 69-83.
27. Kuh, G. D., & Hu, S. (2001). The effects of student-faculty interactions in the 1990s. Review of Higher Education, 24, 309-332.
28. Strayhorn, T. L. (in press). Assessing research self-efficacy among economically disadvantaged undergraduate students of color in mentoring programs at predominantly White institutions. Proceedings of the American Society of Engineering Education.
29. Brock, D. W. (1998). Cloning human beings: An assessment of the ethical issues pro and con. In M. C. Nussbaum & C. R. Sunstein (Eds.), Clones and clones: Facts and fantasies about human cloning (pp. 141-164). New York, NY: Norton.