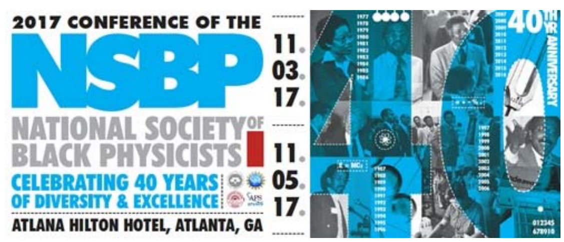
USC Rossier
School of Education

PULLIAS CENTER FOR HIGHER EDUCATION

African American Workforce Development in Physics and Astronomy Workshop

Thursday and Friday, November 2-3, 2017
Morehouse College & Hilton Atlanta, Atlanta, GA

This is a Pre-Conference to the Annual Meeting of the National Society of Black Physicists



A convening of leading experts in K-12 education, Higher Education, Physics/Astronomy, and key stakeholders from industry.

This pre-conference is supported by the National Science Foundation under Grant No. DGE-1663852.

University of Southern California
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PULLIAS CENTER FOR HIGHER EDUCATION

October 20, 2017

Dear NSBP Pre-Conference Participants,

Thank you for agreeing to join us for the upcoming African American Workforce Development in Physics and Astronomy Workshop on **Thursday, November 2nd** and **Friday, November 3rd**. In anticipation of your arrival, we would like you to review the following articles in an effort to build a common starting point for what we know will be fruitful and productive conversations.

- ❑ Center on Education and the Workforce. (2016). *African Americans: College Majors and Earnings*. Georgetown University. Retrieved from https://cew.georgetown.edu/wp-content/uploads/AfricanAmericanMajors_2016_web.pdf
- ❑ Fries□Britt, S. L., Younger, T. K., & Hall, W. D. (2010). Lessons from High-Achieving Students of Color in Physics. In S. Harper & C. Newman (Eds.), *Students of Color in STEM: New Directions for Institutional Research* (Vol. 148, pp. 75–83). Wiley Periodicals, Inc.
- ❑ Ko, L. T., Kachchaf, R. R., Hodari, A. K., & Ong, M. (2014). Agency of Women of Color in Physics and Astronomy: Strategies for Persistence and Success. *Journal of Women and Minorities in Science and Engineering, 20*(2), 171–195.
- ❑ Maton, K. I., Hrabowski, 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.

For your convenience, these articles are included in this packet. Additionally, please find the updated agenda outlining the pre-conference schedule on the next pages.

Looking forward to seeing you all,

Dr. Darnell Cole
Associate Professor, University of Southern California

Dr. Christopher Newman
Associate Professor, University of San Diego

Dr. John Slaughter
Professor of Engineering & Education, University of Southern California

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NSBP Pre-Conference Agenda:

African American Workforce Development in Physics and Astronomy

Day 1: Thursday, November 2nd
2:00pm - 3:00pm
Registration, Hotel Check in (Atlanta Hilton)

3:00pm - 4:00pm
Transportation to Morehouse College

4:00pm - 4:45pm
Pre-Conference Welcome (Morehouse College)

4:45pm - 5:00pm
Introductions (Morehouse College)

5:00 - 6:15pm
Breakout Session #1: Challenges and Barriers to Success (Morehouse College)

6:15pm-7:30pm
Dinner & Reception (Morehouse College)

7:45pm
Transportation back to Atlanta Hilton

Day 2: Friday, November 3rd
8:00am - 9:00am
Continental Breakfast (Atlanta Hilton)

9:00am - 10:00am
Keynote with Dr. S. Gates and Q&A
A View of the Obama's Administration Policy For The American Dream, The Work Force & The 2009-2017 PCAST Reports

10:15am - 11:45am
Breakout Session #2: Successful Interventions/Strategies to Promote Workforce Development

12:00pm - 1:30pm
Lunch and Student Panel (Atlanta Hilton)

1:30pm - 1:45pm
Break

1:45pm - 3:00pm
Breakout Session #3: Creative Solutions & Opportunities for Cross-Collaborations & Future Research

3:00pm - 3:10pm
Break

3:10pm - 4:30 pm
Plenary Session: Vision, Commitments, and Next Steps

4:30pm - 5:00pm
Closing Remarks; Transition to NSBP Conference

AFRICAN AMERICANS
College Majors and Earnings

GEORGETOWN UNIVERSITY
Center on Education and the Workforce
McCourt School of Public Policy

Anthony P. Carnevale | Megan L. Fasules | Andrea Porter | Jennifer Landis-Santos

2016

FACT SHEET

African Americans

College Majors and Earnings

African Americans Concentrated in Low-Paying Majors

Access to college for African Americans has increased, but African Americans are highly concentrated in lower-paying majors. The college major, which has critical economic consequences throughout life, reflects personal choices but also reflects the fact that African-American students are concentrated in open-access four-year institutions that limited choices of majors offered. African Americans represent 12 percent of the US population, but are under-represented in the number of degree holders in college majors associated with the fastest-growing, highest-paying occupations - STEM, health, and business.

African Americans account for only 8 percent of general engineering majors, 7 percent of mathematics majors, and only 5 percent of computer engineering majors.[1] They are similarly under-represented in business: only 7 percent of finance and marketing majors are African-American. In health majors, they account for 10 percent but are clustered in the lowest-earning detailed major: 21 percent are in health and medical administrative services, compared to only 6 percent in the higher-earning detailed major of pharmacy, pharmaceutical sciences, and administration. African Americans are also highly represented in majors associated with serving the community, which tend to be low-earning - human services and community organization (20%) and social work (19%).

Since 2009, there has not been significant change in the proportion of African Americans across majors. One of the most significant changes occurred within the architecture and engineering major group. The percentage of African Americans with industrial and manufacturing engineering or miscellaneous engineering technologies majors decreased by 4 percentage points and 3 percentage points, respectively. Also, the proportion of African Americans in majors where they were already highly concentrated saw a slight increase: social work and health and medical administrative services both increased by 3 percentage points.

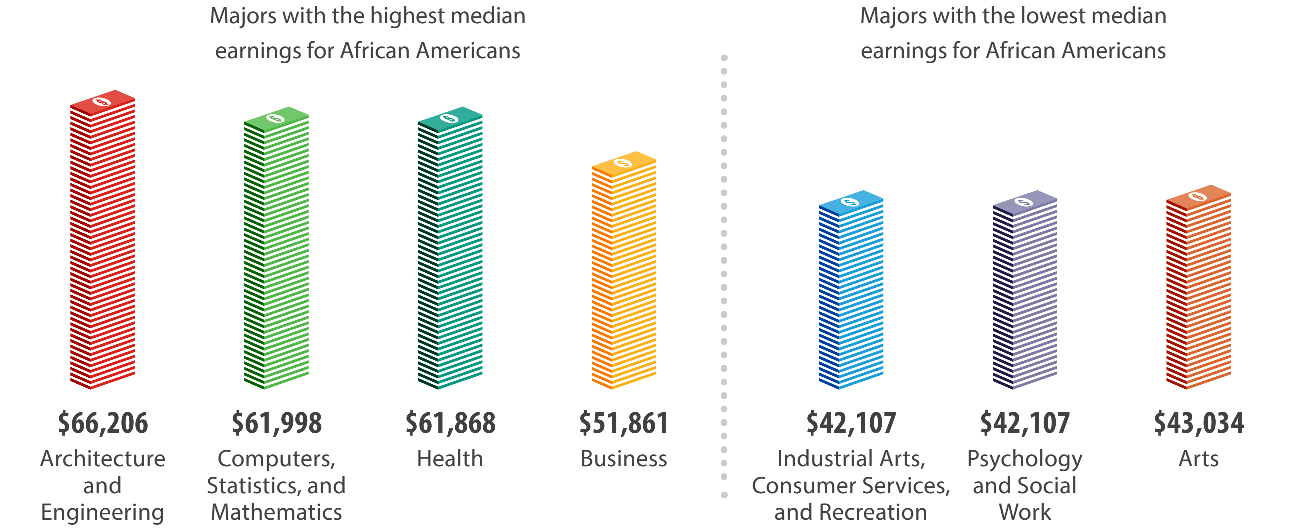
Why Majors and Earnings Matter

Earnings vary greatly among various college majors. African Americans who earned a Bachelor's degree in a STEM-related major, such as architecture or engineering, can earn as much as 50 percent more than African Americans who earned a Bachelor's degree in art or psychology and social work (Figure 1).

---

1 There are 137 detailed majors grouped into 15 general categories. For example, architecture, general engineering, and electrical engineering are all specific majors under the larger grouping of architecture and engineering.

Figure 1. Architecture and engineering is the major group with the highest median earnings for African Americans with a Bachelor's degree.



Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014.

Yet, African Americans account for 12 percent of all Bachelor's degree holders who majored in psychology and social work, and only 5 percent of architecture and engineering majors (Table 1).

Table 1. Concentrations of African American Bachelor's degree holders among major groupings.

Major Group	Percentage African American (%)
Law and Public Policy	15
Psychology and Social Work	12
Health	10
Business	9
Social Sciences	9
Computers, Statistics, and Mathematics	9
Communications and Journalism	8
Physical Sciences	8
Biology and Life Sciences	7
Industrial Arts, Consumer Services, and Recreation	7
Education	7
Humanities and Liberal Arts	6
Architecture and Engineering	5
Arts	5
Agriculture and Natural Resources	3

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014.

Low Representation in the Nation's Fastest Growing Fields

In an analysis of the 137 detailed majors, African Americans who majored in pharmacy, pharmaceutical sciences, and administration have the highest median earnings at $84,000 (Table 2). Industrial/manufacturing, chemical, electrical, mechanical, computer, and civil engineering graduates follow, with median earnings ranging from $68,000 to $76,000.

Table 2. National top 10 median earnings for African Americans with Bachelor's degrees, ranked by highest to lowest earnings (with percentage African American)

Detailed Major	Median Earnings† ($)	Percentage African American (%)
Pharmacy, Pharmaceutical Sciences, and Administration	**84,000**	6
Industrial and Manufacturing Engineering	**76,000**	5
Chemical Engineering	**73,000**	5
Electrical Engineering	**72,000**	6
Mechanical Engineering	**72,000**	3
Computer Engineering	**69,000**	5
Civil Engineering	**68,000**	3
Nursing	**66,000**	10
General Engineering	**66,000**	8
Computer Science	**65,000**	8

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014.

† Earnings at the 50th percentile, ages 25–59

Table 3. National bottom 10 median earnings for African Americans with Bachelor's degrees, ranked by lowest to highest earnings (with percentage African American)

Detailed Major	Median Earnings† ($)	Percentage African American (%)
Early Childhood Education	**38,000**	10
Human Services and Community Organization	**39,000**	20
Area, Ethnic, and Civilization Studies	**39,000**	9
Family and Consumer Sciences	**40,000**	8
Drama and Theater Arts	**40,000**	5
Miscellaneous Industrial Arts and Consumer Services	**40,000**	7
Social Work	**41,000**	19
Physical Fitness, Parks, Recreation, and Leisure	**41,000**	8
Theology and Religious Vocations	**41,000**	11
Philosophy and Religious Studies	**42,000**	6

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014.

† Earnings at the 50th percentile, ages 25–59

African Americans who majored in early childhood education have the lowest median earnings at $38,000 (Table 3). Most of the majors on the list of lowest median earnings for African Americans with Bachelor's degrees tend to be part of intellectual and caring professions - that is, highly-educated workers whose earnings tend not to reflect their years of higher education.

African Americans are most represented in health and medical administrative services, where they account for 21 percent of terminal Bachelor's degrees (Table 4). Human services and community organization has the second-highest percentage of African Americans, and the second-lowest median earnings. In short, African Americans tend to be better represented in majors with the lowest earnings. The 10 detailed majors with the highest percentage of African Americans (Table 4) consist entirely of majors associated with earnings lower than $65,000.

Table 4. African Americans tend to be over-represented in low-earning majors, ranked by percentage of African Americans (with median earnings)

Detailed Major	Percentage African American (%)	**Median Earnings† ($)**
Health and Medical Administration Services	**21**	46,000
Human Services and Community Organization	**20**	39,000
Social Work	**19**	41,000
Public Administration	**17**	52,000
Criminal Justice and Fire Protection	**15**	48,000
Sociology	**14**	44,000
Computer and Information Systems	**14**	63,000
Human Resources and Personnel Management	**14**	51,000
Interdisciplinary Social Sciences	**13**	44,000
Pre-Law and Legal Studies	**13**	46,000

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014.

† Earnings at the 50th percentile, ages 25–59

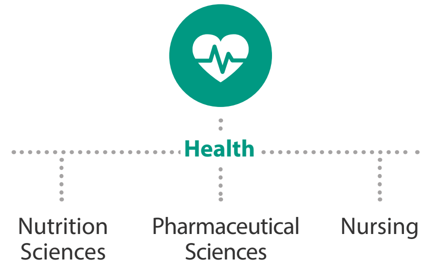
Conclusion

African Americans who choose majors in well-paying, growing fields are likely to be better positioned to get higher paying jobs. This is especially important to a demographic group that historically has been deprived of opportunities and had fewer economic assets and resources making them especially vulnerable to the family stress created by economic ups and downs. Fewer African Americans in high-paying jobs can translate to fewer positive role models of how to be financially successful for younger generations and fewer opportunities to contribute economically to their family and community. Careful career planning is especially crucial for African-American students to help them avoid debt and underemployment later in life.

Majors fall into two categories:

1. Grouped majors are the family of specific majors.
2. Detailed majors, reflect a specialization of study.

For example, Nutrition Sciences, Pharmaceutical Sciences, and Nursing, these are all specific majors under the larger grouping of Health majors.



Median Earnings† ($)		Percentage African American (%)		
		Current	2009	Difference
	Agricultural and Natural Resources			
45,000	General Agriculture	6	3	3
	Architecture and Engineering			
56,000	Miscellaneous Engineering Technologies	9	12	-3
55,000	Industrial Production Technologies	8	9	-1
66,000	General Engineering	8	7	1
72,000	Electrical Engineering	6	6	0
73,000	Chemical Engineering	5	5	0
53,000	Architecture	5	4	1
76,000	Industrial and Manufacturing Engineering	5	9	-4
72,000	Mechanical Engineer	3	3	0
68,000	Civil Engineering	3	3	0
	Arts			
43,000	Music	7	6	1
40,000	Drama and Theater Arts	5	5	0
43,000	Commercial Art and Graphic Design	5	5	0
45,000	Fine Arts	4	5	-1
	Biology and Life Sciences			
47,000	Biology	9	9	0
	Business			
51,000	Human Resources and Personnel Management	14	13	1
51,000	Business Management and Administration	12	10	2
53,000	Miscellaneous Business and Medical Administration	10	7	3
52,000	General Business	9	8	1
63,000	Management Information Systems and Statistics	9	9	0
56,000	Accounting	8	8	0
53,000	Operations, Logistics, and E-Commerce	7	7	0
57,000	Finance	7	6	1
48,000	Marketing and Marketing Research	7	7	0
44,000	Hospitality Management	6	4	2

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Detailed majors with less than 100 observations are not included in this analysis. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014 and Carnevale, Strohl, and Melton, *What's It Worth?*, 2011.

† Earnings at the 50th percentile, ages 25 – 59

Appendix. All Majors by Group for African Americans with Bachelor's Degrees
by Median Earnings and Degree Concentration

Median Earnings† ($)		Percentage African American (%) Current	2009	Difference
	Communications and Journalism			
47,000	Communications and Mass Media	9	9	0
46,000	Journalism	7	7	0
47,000	Advertising and Public Relations	6	6	0
	Computers, Statistics, and Mathematics			
63,000	Computer and Information Systems	14	13	1
61,000	Information Sciences	11	12	-1
53,000	Miscellaneous Computer	9	--	--
65,000	Computer Science	8	9	-1
62,000	Mathematics	7	6	1
69,000	Computer Engineering	5	4	1
	Education			
51,000	Miscellaneous Education	11	10	1
38,000	Early Childhood Education	10	10	0
47,000	Physical and Health Education Teaching	9	7	2
44,000	General Education	9	9	0
48,000	Special Needs Education	7	8	-1
45,000	Secondary Teacher Education	5	6	-1
44,000	Elementary Education	5	5	0
47,000	Language and Drama Education	5	4	1
44,000	Art and Music Education	4	4	0
	Health			
46,000	Health and Medical Administrative Services	21	18	3
50,000	Miscellaneous Health Medical Professions	10	10	0
66,000	Nursing	10	9	1
84,000	Pharmacy, Pharmaceutical Sciences, and Administration	6	5	1
49,000	Treatment Therapy Professions	6	6	0
	Humanities and Liberal Arts			
43,000	Multi/Interdisciplinary Studies	12	--	--
41,000	Theology and Religious Vocations	11	12	-1
39,000	Area, Ethnic, and Civilization Studies	9	8	1
46,000	Liberal Arts	9	7	2
46,000	English Language and Literature	6	6	0
42,000	Philosophy and Religious Studies	6	6	0
47,000	History	5	5	0
44,000	French, German, Latin, and Other Common Foreign Language Studies	4	4	0

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Detailed majors with less than 100 observations are not included in this analysis. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014 and Carnevale, Strohl, and Melton, *What's It Worth?*, 2011.

† Earnings at the 50th percentile, ages 25 – 59

Appendix. All majors by group for African Americans with Bachelor's Degrees
by Median Earnings and Degree Concentration

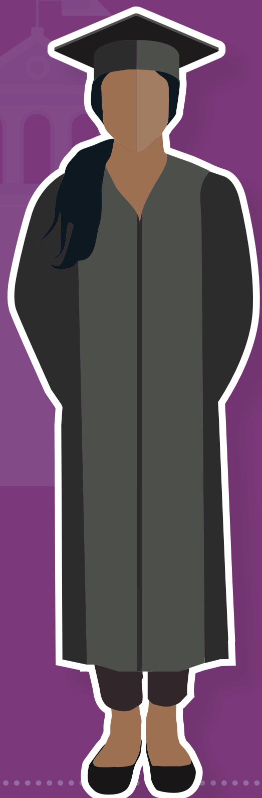
Median Earnings[†] ($)		Percentage African American (%) Current	2009	Difference
	Industrial Arts, Consumer Services, and Recreation			
40,000	Family and Consumer Sciences	8	8	0
41,000	Physical Fitness, Parks, Recreation, and Leisure	8	8	0
40,000	Miscellaneous Industrial Arts and Consumer Services	7	--	--
61,000	Transportation Sciences and Technologies	5	6	-1
	Law and Public Policy			
52,000	Public Administration	17	18	-1
48,000	Criminal Justice and Fire Protection	15	14	1
46,000	Pre-Law and Legal Studies	13	14	-1
	Physical Sciences			
52,000	Multidisciplinary or General Science	11	10	1
49,000	Chemistry	8	7	1
	Psychology and Social Work			
39,000	Human Services and Community Organization	20	21	-1
41,000	Social Work	19	16	3
43,000	Psychology	10	9	1
	Social Sciences			
44,000	Sociology	14	14	0
44,000	Interdisciplinary Social Sciences	13	9	4
49,000	General Social Sciences	13	13	0
46,000	Criminology	10	9	1
50,000	Political Science and Government	9	8	1
55,000	Economics	6	6	0

Bachelor's degree holders refer to adults between the ages of 21 and 59 with a Bachelor's degree but no graduate degree. Earnings data are reported for workers employed full-time, full-year. Detailed majors with less than 100 observations are not included in this analysis. Source: Georgetown University Center on Education and the Workforce analysis of U.S. Census Bureau, *American Community Survey* microdata, 2010-2014 and Carnevale, Strohl, and Melton, *What's It Worth?*, 2011.

[†] Earnings at the 50th percentile, ages 25 – 59

African Americans

College Majors and Earnings



Prevalence of African-American Bachelor's Degree Holders

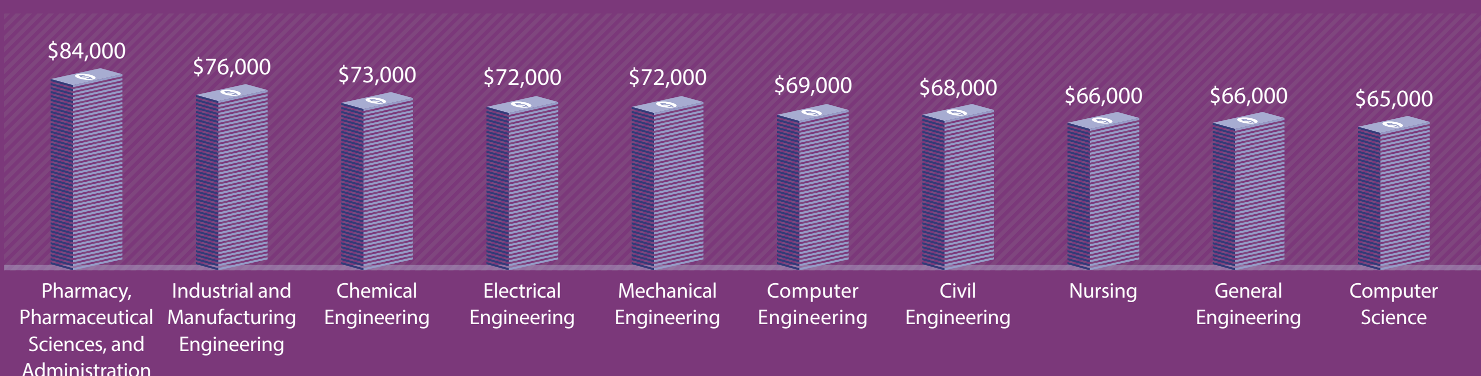
African Americans tend to be over-represented in low-earning majors

Top 10 Majors by Percentage of African-American Bachelor's Degree Holders

1 – **Health and Medical Administration Services,** 21%
2 – **Human Services and Community Organization,** 20%
3 – **Social Work,** 19%
4 – **Public Administration,** 17%
5 – **Criminal Justice and Fire Protection,** 15%
6 – **Sociology,** 14%
7 – **Computer and Information Systems,** 14%
8 – **Human Resources and Personnel Management,** 14%
9 – **Interdisciplinary Social Sciences,** 13%
10 – **Pre-Law and Legal Studies,** 13%

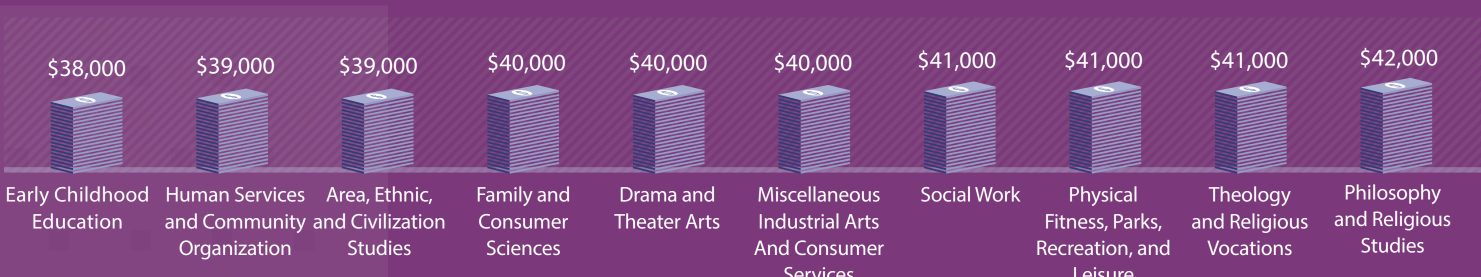
10 Highest-Earnings Majors for African Americans

African Americans who majored in pharmacy, pharmaceutical sciences, and administration have the highest median earnings at $84,000.



10 Lowest-Earnings Majors for African Americans

Most of the majors on the list of lowest median earnings for African Americans with Bachelor's degrees tend to be part of intellectual and caring professions - that is, highly educated workers whose earnings tend not to reflect their years of higher education.



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To view the research this graphic is based on, download *African Americans: College Majors and Earnings*.

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ACKNOWLEDGEMENTS

We would like to express our gratitude to the individuals and organizations whose generous support has made this report possible: **Lumina Foundation** (Jamie Merisotis and Holly Zanville), **The Bill & Melinda Gates Foundation** (Daniel Greenstein and Jennifer Engle) and **The Joyce Foundation** (Matthew Muench). We are honored to be partners in their mission of promoting postsecondary access and completion for all Americans.

Many have contributed their thoughts and feedback throughout the production of this publication. We are grateful for our talented designer, Tim Duffy and meticulous editorial advisor Tracy Thompson, whose tireless efforts were vital to our success.

In addition, the dedication of Georgetown CEW's economists, analysts, writers, communications team, and operations staff were instrumental to production of this report, from conceptualization to completion:

- Jeff Strohl - research direction
- Hilary Strahota, Vikki Hartt – communications efforts
- Joe Leonard, Coral Castro – logistics and operations

The views expressed in this publication are those of the authors and do not necessarily represent those of Lumina Foundation, the Bill & Melinda Gates Foundation, the Joyce Foundation, or their officers or employees.

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7

This chapter is based on a multiyear study of 110 physics majors at colleges and universities across the United States. Its focus was on understanding their interactions with faculty and peers, experiences in their respective physics programs, and the extent to which they were motivated by race to succeed as scientists.

Lessons from High-Achieving Students of Color in Physics

Sharon L. Fries-Britt, Toyia K. Younger, Wendell D. Hall

Several national reports highlight a growing concern about the erosion of science and technology education in the United States (National Action Council for Minorities in Engineering, 2008; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). For example, *Rising Above the Gathering Storm* (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007) emphasizes the social and economic impact this decline may have on individuals who intend to compete for high-quality jobs in science, technology, engineering, and mathematics (STEM) fields and the negative effect this can have on the ability of the United States to compete in a global scientific environment. This focus on STEM fields has resulted in a call for colleges and universities, as well as national organizations (for example, the National Science Foundation), to address several challenges, including attrition among undergraduate students who, on admission to their institutions, had aspired to pursue careers in STEM fields.

Despite changing demographics in the United States, students of color have remained woefully underrepresented in STEM fields. While African American, Native Americans, and Latinos make up over 30 percent of the undergraduate student population in this country, less than 12 percent of baccalaureate degrees in STEM fields are awarded to persons

This study was supported by the National Society of Black Physicists and partial funding from the Sloan Foundation.

Published online in Wiley Online Library (wileyonlinelibrary.com) • DOI: 10.1002/ir.363

from these racial groups (National Action Council for Minorities in Engineering, 2008). Despite an increase in women and underrepresented minorities pursuing graduate degrees in STEM fields, their participation is still significantly less than that of their White counterparts, and they often have higher rates of attrition (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Science Foundation, 2000). This suggests that significant work must be done to increase and sustain the interest of underrepresented students in STEM.

Equally important is the need to understand the experiences of undergraduates who are currently enrolled in STEM fields. We know from previous research (for example, Seymour and Hewitt, 1997) that the nature of the first two years of undergraduate study in STEM fields is overly competitive and unfriendly, particularly toward women and students of color. Furthermore, many students perceive that during their freshman and sophomore years, there is an attempt to weed them out of STEM majors by requiring them to take extraordinarily difficult classes. Seymour and Hewitt maintain that campuses must acknowledge and address the fact that weed-out courses often heighten feelings of alienation among some students in STEM. These unsupportive learning communities contribute to students' leaving the sciences, while those who persist often study in isolation and typically have little interaction with peers, STEM faculty, or teaching assistants outside the classroom.

In this chapter, we describe a five-year study with the National Society of Black Physicists (NSBP) and the National Society of Hispanic Physicists (NSHP). The purpose of our research was to understand the academic, social, and racial experiences of students of color who were succeeding in physics. We defined success based on criteria established by NSBP and NSHP for student participation in their national conferences. Those selected for the conferences were required to be in good academic standing and persisting toward degree completion as verified by their department chairs and academic advisors. In addition, each student was required to complete a form listing the physics-related courses in which she or he was enrolled at that time.

Study Description

Several key questions guided the study:

- What factors identified as important to racial minority student success in the literature (for example, faculty, peers, familial, and financial) applied to the experiences of students of color majoring in physics?
- In what ways did racial minority students in physics characterize their experiences?
- What perceptions did students have about their interactions with faculty inside and outside the classroom?

- Did race contribute to their motivation to succeed?
- How did their academic experiences shape their overall sense of self?

We relied on a range of theories and bodies of research to build a conceptual framework for this study. First, we turned to the retention and college impact literature (Astin, 1993; Tinto, 1993; Pascarella, 1980), which informed our understanding of factors salient to student success in college. Astin's (1993) input-environments-outcome (I-E-0) model was particularly useful in conceptualizing the academic environment. Astin noted, "The environment encompasses everything that happens to a student during the course of an educational program that might conceivably influence the outcomes under consideration" (p. 81). Next, we turned to the literature that identifies a number of barriers that hinder the success of students of color in STEM (National Action Council for Minorities in Education, 2008; Busch-Vishniac and Jarosz, 2004; Cabrera, Colbeck, and Terenzini, 2001; Seymour and Hewitt, 1997).

We then engaged several psychological concepts like self-efficacy (Bandura, 1977) and attribution theory (Fishbein and Ajzen, 1975) to help inform our understanding of individual behaviors and perceptions. The growing research on racial minority high achievers (Fries-Britt, 1998; Fries-Britt and Griffin, 2007; Fries-Britt and Turner, 2002; Griffin, 2006; Harper, 2008, 2009; Hrabowski, Maton, and Greif, 1998, 2002) offered yet another dimension and way of understanding factors that contribute to student success. While the conventional approach of using previously published literature to identify trends guided the overall method for this study, we also remained open to new and emerging data throughout the course of the project. This constructivist approach (Manning and Stage, 2003) allowed us to incorporate new information that was useful in reshaping the interview protocol for subsequent years.

Data collection occurred annually at meetings of the NSBP and NSHP. Of the 110 students in the study, 35 percent were women. Participants attended a variety of colleges and universities: private, public, predominantly White, historically Black, as well as Hispanic-serving institutions from different regions of the country. In combination with individual interviews and small focus groups, we conducted document analysis. Specifically, we reviewed annual reports and previous conference programs. We also collected field notes from conference sessions, keynote addresses, and student gatherings. In addition, our data collection included interviews with key staff persons who worked closely with the NSBP.

We audiotaped and transcribed verbatim all individual interviews and focus groups. We used the NVivo software program to manage and code the data. We established the initial coding structure based on the interview protocol. After reviewing the earliest transcripts, we revisited the coding categories and made necessary changes. We initially created two coding teams to validate the categories and used one coding team during the last two years of the project.

Summary of Key Findings

For the purposes of this chapter, we have organized our findings around three factors that from our conceptual framework: interactions with faculty, the role of peers, and the proving process characterized by Fries-Britt and Turner (2002).

What Faculty Say and Convey Matters. Not surprisingly, participants in our study had both positive and negative interactions with faculty. What mattered was what faculty said to students and how they conveyed their confidence or lack of assurance in students' abilities. Participants talked about the tone professors used to speak with them and how their body language communicated approachability (or lack thereof). Students perceived these as conveying directly or indirectly what a professor thought of their work and ability to do well in science. In some instances, students' perceptions were that these interactions were race related. They offered vivid examples of how professors were positive and negative in what they communicated. A common experience was that professors tried to discourage them from science by either blatantly recommending they find another major or by ignoring their contributions in the classroom.

The positive behaviors of faculty were equally revealing. Students talked about professors who acknowledged their academic abilities, intentionally sought them out to participate in research projects, and confirmed for students that they had a talent for science. Many participants described ways in which faculty members inspired them by sharing their own struggles and telling them they understood their fears. Interestingly, the majority of professors who were reportedly open to discussing their own experiences were racial minorities or women. However, we learned from the participants that good faculty mentors do not always have to be the same race as their students to be effective. What does matter is that professors are genuinely interested in students' success. Participants offered examples of what professors did to make learning fun, which included something as simple as talking with inflection, showing an interest in and an excitement toward physics, and finding relevant ways to teach the subject and engage students in the classroom.

Peers Make a Major Difference. The majority of the students we interviewed reported having excellent relationships with peers in their respective academic programs. Many described physics peers as the "saving grace" and that they otherwise would not have "made it" in STEM were it not for peer support. One reason offered for the closeness of students in physics is that other students often perceive them as different from nonscience majors and even other STEM majors. Another factor is that students in the sciences spend considerable time working in labs and solving problems collaboratively, which easily spilled over into social time together. Students attending historically Black colleges and universities (HBCUs) were more likely to describe a family-type environment among peers and faculty, whereas fewer students at predominantly White institutions (PWIs) reported feeling close to their peers. Moreover, participants enrolled in smaller programs were more likely to describe more interaction and stronger connections with their peers.

Participants did not consider all interactions that occurred with peers in physics as positive. Some students indicated that it was important for them to have friends outside the major and other sciences fields. International students tended to talk about the importance of having a diverse group of friends and activities outside of physics. Many of their friends were other international students in nonscience fields. Some students encountered more intense competition and did not necessarily feel that they had supportive peers. In some programs, students noted that international students tended to help each other and did not spend as much time with American-born students.

The Never-Ending Proving Process. Students often reported feeling as if they had to prove themselves in the classroom no matter how long they persisted in physics. Each semester they had to start over with a new professor, or even the same professor but in a different course, and prove they could handle the work. They also expressed frustration with having to prove to people that they deserved to be admitted into top programs and, if they attended lesser-known schools, that they were just as capable as students in more competitive programs. Some graduate students, especially those who had completed their undergraduate degrees at HBCUs, expressed this same sentiment. Many of these participants shared examples of how their enrollment in graduate-level physics programs at PWIs was questioned because of the institutions at which they earned their baccalaureate degree.

Additional Noteworthy Findings. Other key findings in our study reveal that many participants were motivated to pursue science early in their academic careers by K–12 teachers who affirmed their talents and abilities. In addition, parents also played an important role in introducing students to science. Some students grew up in households where at least one parent was a scientist. Others had parents who exposed them early to science activities. The data reveal that students' experiences may differ considerably based on institutional choice and ways in which programs socialize students, offer them resources, and expose them to various aspects of the field.

We also found that many international students reported different perceptions and experiences than their U.S.-born counterparts. Often these differences centered on perceptions of race, equity, and diversity. Gender issues emerged as some female students encountered sexist comments and exclusion from activities, which created a chilly climate for them. However, these experiences were not pervasive. What the data show is that women anticipated a degree of bias in the sciences and prepared themselves for this prior to entry into their physics programs; such negative experiences in fact motivated them to succeed.

Implications for Research

This study reveals that many students were motivated to pursue science early by K–12 teachers and their parents. Scholars need to study the K–12 environment and the practices of teachers, parents, and other adults who inspire students to pursue science. How do these adults engage students, and what do they say to inspire them? More important, how aware are they of the impact they may have on students' development of aspirations in the sciences? From this line of research, we can make necessary changes to teacher preparation programs and learn valuable pedagogical techniques. We can also help parents understand what activities and practices matter in early skill development and sustaining long-term enthusiasm for science. Ultimately we can expand our understanding of the ways that early education can create pathways to college in general and STEM majors in particular.

Similarly, our findings suggest a need to know more about the behaviors of professors who inspire students to succeed in science as well as behaviors and practices that impede their success. Researchers should seek to identify the pedagogical techniques used by faculty that build analytical skills and subject mastery and inspire confidence in students. We need to know more about how professors acknowledge and respond to the myriad learning styles of their students in diverse classroom environments. Even more important, researchers must seek to better understand the extent to which faculty are aware of classroom dynamics that are fostered because of their interactions with students. A consistent sentiment that participants shared is that faculty often make comments that rendered their contributions insignificant. Because of these interactions, students felt less confident in classrooms and often began to disengage. Participants made clear they were not looking for faculty to be "nice"; rather, they desired assistance and an honest assessment of their work without rendering them incompetent or undeserving.

We also need additional research to understand more about expectations faculty and students have for interacting with each other outside the classroom. Our work indicates that students appreciate these interactions, and getting to know professors makes it easier to engage with them on academic matters. Students reported a wide range of out-of-class interactions with faculty, including working on research, playing sports, sharing meals, attending cultural events together, and spending time at a professor's home. What we do not know is how faculty members interpret and value these interactions. We also need a greater understanding about how STEM professors make decisions regarding the expenditure of time with their students beyond the classroom. How do they balance the competing demands of the academy? Finally, what, if any, concerns do they have about engaging with students? Research in this area will reveal challenges for faculty and students, as well as identify mutually beneficial opportunities for interacting outside the classroom.

Another important implication for research is engagement and learning in diverse classrooms. In this study, many students reportedly faced stereotypes and erroneous assumptions about their academic abilities based on race and gender. Many students felt pressure to "prove" to their peers that they were academically capable before they were invited into study groups. They described specific behaviors exhibited by group members that made them feel excluded. Even when faculty assigned them to groups, they still felt as if they had to prove to the rest of their peers that they had something to contribute before others considered them legitimate group members. Often they achieved their legitimacy when they proved to be the only person in the group who was able to solve a problem. Future research should focus on better understanding these dynamics.

Finally, while we know there is an abundance of research on differences between PWIs and HBCUs in retaining minority students in sciences, there is room for continued exploration of these institutional differences. We believe it is important to continue to explore the role of institutions in fostering the conditions necessary for success. Our study indicates that we need to continue to understand more about what HBCUs are able to do with limited resources. We believe there are many lessons we can learn from these environments about how to nurture, support, and cultivate student achievement in science.

Conclusion

There is no better time to respond to calls to increase the participation of persons of color in STEM. The progress we make over the next several years will have long-term effects on our nation's ability to compete globally and establish a stronger enthusiasm for science in communities of color. A large part of our success will be in simultaneously studying and better understanding students currently in the pipeline, as well as the experiences of professionals of color in STEM.

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AGENCY OF WOMEN OF COLOR IN PHYSICS AND ASTRONOMY: STRATEGIES FOR PERSISTENCE AND SUCCESS

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Women of color are widely considered to be valuable sources of talent to fill U.S. science, technology, engineering, and mathematics (STEM) occupations. However, they are continually underrepresented in advanced degree attainment and leadership positions relative to their male and White female counterparts. To explore factors of persistence and success, the NSF-funded Beyond the Double Bind study elicited life stories from 22 women of color with bachelor's and advanced degrees in physics or astronomy, two of the most exclusive STEM fields. The study found that these women commonly experienced social isolation, yet they were not passive victims of their departmental cultures. To persist in science, they employed multiple forms of agency, including eight navigational strategies: seeking an environment that enabled success, circumventing unsupportive advisors, combating isolation using peer networks, consciously demonstrating abilities to counteract doubt, finding safe spaces for their whole selves, getting out to stay in STEM, remembering their passion for science, and engaging in activism. These findings point to specific barriers that could have been remedied by institutional change so that the large amount of time and energy minority women invested in strategies for persistence could have been spent doing science. Since relying on women of color to adjust their actions and behaviors to survive existing STEM climates is not a long-term solution, the article concludes with recommendations for two groups: women of color who seek to succeed in STEM fields, and institutions of higher education and employers dedicated to retaining women of color and broadening participation in STEM.

KEY WORDS: *science, STEM, astrophysics, minority, race, gender, navigation, coping, mentoring*

1. INTRODUCTION

Women of color—women who identify as Black, Latina, Native American, and Asian American[1]—are widely considered to be valuable sources of talent to fill U.S. science, technology, engineering, and mathematics (STEM) occupations (Committee on Equal Opportunities in Sci-

[1]We use the racial categories *Latina*, *Native American*, and *Asian American* throughout the paper. NSF's analogous terms are, respectively, *Hispanic*, *American Indian/Alaska Native*, and *Asian or Pacific Islander.*

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ence and Engineering [CEOSE], 2009, 2011; National Research Council, 2010, 2011; Ong et al., 2011). Despite encouraging inroads made over the last three decades by women and minorities into STEM generally, data show that physics and astronomy remain overwhelmingly White and male. Black, Latina, and Native American women, commonly identified as underrepresented minority (URM) women, are especially underrepresented in advanced degrees and careers in these fields (National Science Foundation [NSF], 2013). In 2010, while URM women comprised 14.03% of the U.S. resident population (ages 25–64[2]), they received only 1.72% of all doctoral degrees awarded in physics and astronomy (see Fig. 1) (NSF, 2013).

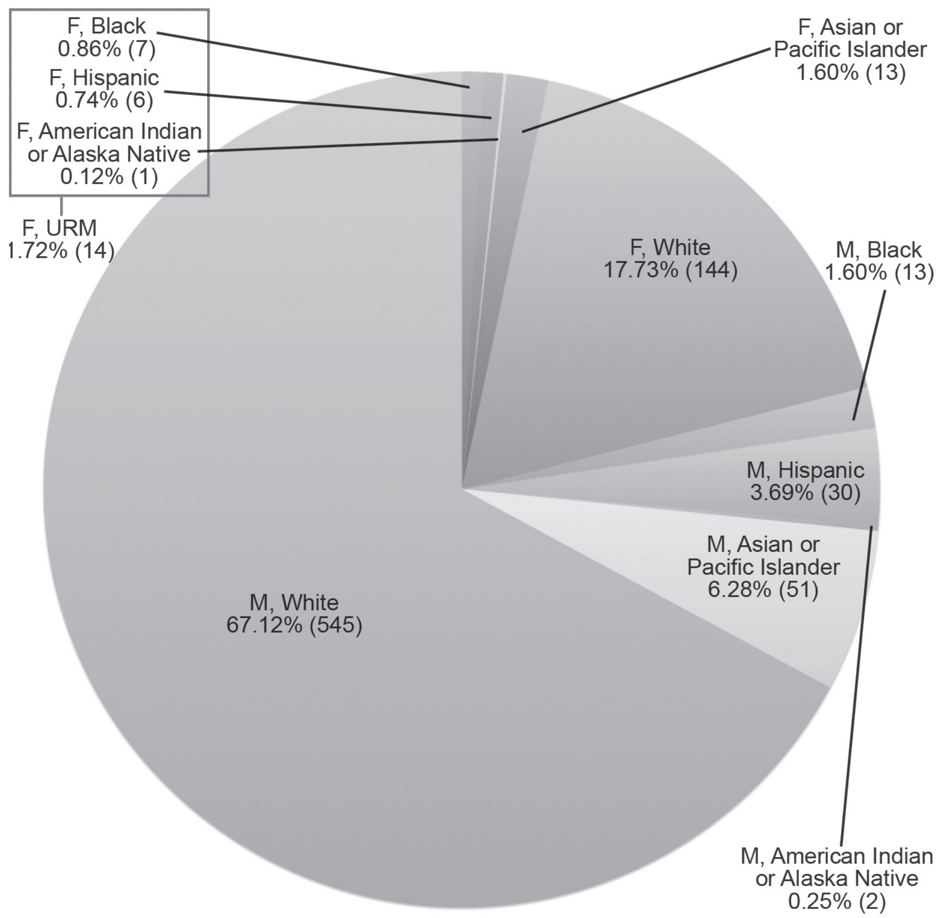

FIG. 1: Physics and astronomy doctoral degrees earned by race and gender: 2010 (NSF, 2013)

[2]The U.S. resident population data available from NSF were presented in the following age categories: *Younger than 5, 5–17, 18–24, 25–64,* and *65 and older*. We selected the *25–64* category because it most closely approximates the typical age range of Ph.D. recipients.

In physics and astronomy, Asian American women are also underrepresented. In 2010, they made up 2.83% of the U.S. resident population (ages 25–64); yet in the same year, as Fig. 1 shows, they received just 1.60% of all physics and astronomy Ph.D.s awarded (NSF, 2013). Furthermore, like their URM female counterparts, Asian American women have been—and continue to be—stalled in junior- or mid-level positions, not advancing to leadership positions at pace with their male and White female counterparts (Burrelli, 2009; Wu and Jing, 2011, 2013).

Women of color—who dually occupy the particularly undervalued identities of femaleness and non-Whiteness (Ong, 2008; Traweek, 1988)—often experience personal, professional, and societal challenges to a degree that White women and minority men do not (Crenshaw, 1993; Hamilton, 2004; Lugones, 1994; Wei, 1996). The following comment by Dr. Evelynn Hammonds, a former physicist and current historian of science, provides an illustration of the ways in which race and gender function *simultaneously* to produce this complex outcome. In recalling an exchange with a former fellow scientist at Bell Labs, she says:

> *[Race and gender] are not separate. Because they aren't separate in me. I am always Black and female. I can't say, "Well, that was just a sexist remark" without wondering would he have made the same sexist remark to a White woman. So, does that make it a racist, sexist remark? You know, I don't know. And that takes a lot of energy to be constantly trying to figure out which one it is. I don't do that anymore, I just take it as, you know, somebody has some issues about me and who I am in the world. Me being Black, female, and wanting to do science and be taken seriously. (E. Hammonds, in Sands, 1986, p. 14)*

Critically, this narrative by Dr. Hammonds underscores how the *intersection* of her race and gender affected her professional experiences: it cost her, at least in the earlier part of her career, "a lot of energy" that might have been more productively spent on practicing science. This example illustrates the kinds of complexities and trade-offs that challenge women of color as they pursue careers in science.

Unfortunately, very little empirical research has examined the causes of women of color's underrepresentation in, and attrition from, STEM higher education and careers. In the studies that do exist from the last two decades, research suggests that the primary cause is social isolation comprised of factors such as challenging interpersonal relationships with professors, supervisors, and peers; low expectations from others; and lack of mentoring and support (Brown, 2000b; Brown, 2000a; Carlone and Johnson, 2007; D. Johnson, 2007; Joseph, 2012; Justin-Johnson, 2004; MacLachlan, 2006; Ong, 2005; Ong et al., 2011; Shain, 2002; Tate and Linn, 2005). A related body of literature on females and minorities in education suggests that, far from being passive victims of their isolating STEM environments, women of color serve as active agents in their own educations and careers (DeWelde and Laursen, 2011; Johnson et al., 2011; Joseph, 2012; Ong, 2005).

Despite years of underrepresentation and isolation, some women of color persist and thrive in STEM. Our recent study, *Beyond the Double Bind: Women of Color in Science, Technology, Engineering, and Mathematics*, set out to answer the question: *What strategies enable women of color to achieve higher levels of advancement in STEM education and professions?* The study confirmed experiences of isolation, but crucially, it also elicited stories of persistence and advancement. In this paper, we focus on two fields where women of color are most underrepresented, physics and astronomy (NSF, 2013). We present eight navigational strategies drawn from narratives of women of color who have advanced in these fields and examine how these strategic actions contributed to persistence and success.

An examination of these strategies is important because it can help improve the experiences of and policies for women of color in STEM in several ways:

1. Broad evidence of agentic activities counteracts narratives that position women of color as passive victims of their environments and provides models for persistence and success.
2. Narratives about how these strategies are used shed light on specific barriers to success in STEM that could be remedied by institutional change.
3. These accumulated strategies bring into relief the large amount of time and energy that women of color must spend on non-science activities in order to succeed in science, compared to individuals of White and/or male backgrounds (Carlone and Johnson, 2007; Ong, 2005; Ong et al., 2011; Varma, 2002).

By identifying these strategies through analysis of interviews and personal narratives, this paper is able to present the often-unheard voices of women of color who have struggled, and yet are succeeding in physics and astronomy.

2. REVIEW OF RELEVANT LITERATURE

The challenges facing women of color in STEM were first brought to national attention in *The Double Bind: The Problem of Being a Minority Woman in Science* by Malcom, Hall, and Brown (Malcom et al., 1976). Since then, only a small number of studies have further explored the experiences of this population and how to advance them in their fields. Many of the studies investigating the experiences of women of color in STEM identified isolation as a common and significant hindrance to advancement. This isolation resulted from unwelcoming environments of academic departments and workplaces and from the fact that women, especially women of color, were often treated differently than their White male peers (A. Johnson, 2007; Ortiz, 1983). Additionally, Johnson (2011) found that, in contrast to White women, women of color were often numerically the only ones in their environments, and they were documented as feeling a lesser sense of belonging, as well as holding less positive views of their campus climates (also see Dickey, 1996; Varma et al., 2006). Feelings of isolation were found to be great for women of color who transitioned from minority-serving institutions to predominantly White institutions (Joseph, 2012; Valenzuela, 2006).

Some studies determined that isolation from peers, in combination with racism and/or sexism, constituted a STEM environment that negatively affected women's everyday experiences. Some studies determined that isolation from peers constructed a STEM environment in which racist and/or sexist micro-aggressions (subtle offenses) played out in classrooms, laboratories, and informal spaces (Brown, 2000a; Joseph, 2012; MacLachlan, 2006). Other works, including this study, found that women of color experienced isolation both inside classrooms and laboratories and in social settings, such as exclusion from after-work outings, where important conversations regarding science continued (Espinosa, 2011; Justin-Johnson, 2004; Shain, 2002; Valenzuela, 2006). Furthermore, some studies found that these experiences of isolation conflicted with women of color's academic preferences to collaborate and work with classmates (e.g., Espinosa, 2008).

To date, much of the language used in the research on women of color in isolating STEM climates has depicted women as passive participants in their STEM experiences. In describing why more women of color do not advance to the tops of their fields, the “leaky pipeline” metaphor is often deployed. In this model, women or girls of color are put in at the beginning of the pipeline, flow through various stages of STEM, and “leak out” at different points (Blickenstaff, 2005). This metaphor has come under recent criticism for failing to acknowledge women of color’s inherent agency and choices as they navigate their STEM experiences (Branch, 2013; Johnson et al., 2011; Malcom and Malcom, 2011; Metcalf, 2010). The metaphor assumes passivity and, moreover, no diversity in how or at what points women of color enter STEM, which may vary greatly depending on individual backgrounds (e.g., Husbands Fealing and Myers, 2012; Metcalf, 2010; Reyes, 2011). Malcom and Malcom (2011) reference the CEOSE report (2004) to further explain that the pipeline metaphor often emphasizes student-level characteristics and minimizes the role of institutions, thereby placing blame on women of color due to supposedly inherent characteristics, while failing to acknowledge the women’s own attempts to navigate institutional environments. A more accurate metaphor may be the roadway or pathway with a wide variety of on-ramps, exits, potholes, routes, and destinations (Branch, 2013; Reyes, 2011). The pathways metaphor allows for the agency of women of color and “highlights the role of institutions in shaping underrepresented students’ participation and outcomes in science…while acknowledging the importance of institution-specific contextual factors that often constrain the acquisition of resources and opportunity and inhibit student success” (Malcom and Malcom, 2011, p. 165).

Agency for women of color in STEM is a largely unexplored area. However, some studies have identified agentic navigational strategies used for coping in STEM environments. The synthesis conducted by Ong et al. (2011) found that one strategy used by women of color was “spen[ding] a lot of time and energy changing how they dressed, spoke, and presented themselves to others—partially masking their gendered or raced selves—in order to gain acceptance within their STEM communities” (p. 193). This synthesis included Ong’s earlier (2005) study that examined the ways in which ten minority undergraduate female physics students sensed that their belonging and competence in science were questioned because their bodies did not conform to prevalent images of the “ordinary” White male physicist. As a form of agency to persevere in physics, these women engaged in either fragmentation (downplaying aspects of their race or gender) or multiplicity (stereotype manipulation or performances of superiority). DeWelde and Laursen (2011) also found that women pursuing a Ph.D. in the STEM fields compromised or masked feminine characteristics such as feminine dress, purposefully participating in having beers with “the guys” and playing sports.

Carlone and Johnson (2007) described a process of creating science identities that served as a coping strategy for women of color in STEM. In one example, women in their study with the “altruistic scientist” identity supported themselves in difficult environments by viewing science as a vehicle for altruism, redefining whose recognition of them as scientists mattered to them, and finding advantages to identifying as a minority in science. The authors acknowledged individual agency in this model and that these women fought for their identities, forming and reforming them in different contexts. In a subsequent study, Johnson et al. (2011) found that women of color attempted to author their own science identities, but that they were not always successful, as others around them in positions of power did not recognize their efforts.

In one of the few quantitative studies that examines experiences of women of color in STEM, Espinosa (2011) also found aspects of identity to be crucial to women of color’s success. Her investigation into the impact of relationships between pre-college characteristics (e.g., high school GPA), college experiences (e.g., frequency of faculty interactions), and institutional settings (e.g., percent of undergraduates enrolled in STEM majors) on the persistence of undergraduate women of color in STEM majors found that a strong science identity was important. The agentic strategies of those who succeeded included engaging with peers on course content, joining student organizations, and participating in research. With similar findings in a qualitative study, Joseph (2012) focused on the experiences of six Black women as they transitioned from undergraduate experiences at historically Black colleges or universities to predominantly White institutions for graduate study. Joseph found that students with a strong sense of personal identity were "less likely to allow others to minimize their potential" (p. 131). Often challenged by the content of their graduate courses, the students employed agentic strategies that included reaching out to instructors, teaching assistants, and tutors to help with course work and carrying a more business-like manner with peers.

Although a few studies have investigated agency as a factor of success for women of color in STEM, more details are needed about how these strategies are carried out in response to isolation and lack of institutional support. The *Beyond the Double Bind* study, on which our analysis is based, contributes substantially by providing a data set focused on specific strategies used to navigate STEM environments and by identifying concrete tactics of women of color's agentic activity.

3. METHODS

Our data were drawn from the larger study, *Beyond the Double Bind*, a four-year National Science Foundation-funded project in which we studied women of color in physics, astronomy, computer science, and engineering to discover the strategies that worked to enable women of color to achieve higher levels of advancement in STEM academia and professions. This paper focuses only on participants in physics and astronomy, two fields in which minority women are most underrepresented in STEM.

3.1 Data Collection

The data set for this study consisted of narratives—extant texts and interviews—of 22 women of color in physics and astronomy, of varying career stages and racial groups, shown in Table 1.

TABLE 1: Participants by career stage and race

Career stage		Race	
Graduate student	4	Black	13
Postdoctoral fellow	1	Asian American	2
Early-career	3	Latina	6
Mid-career	5	Native American	1
Late-career	9		

3.1.1 Extant Texts

Extant texts are defined by Charmaz (2006) as various publicly available documents that researchers have no hand in shaping and are not written for the purposes of the research, but are treated as data to address the research question. We gathered 38 extant texts on 13 women of color. The texts included autobiographies, biographies, interviews, news articles, journal articles and personal essays. They were published within the last ten years and located largely in books, magazines, and online sources, which were utilized by conducting searches of key terms related to women of color and STEM. Selection criteria required the texts to include full descriptions or stories of personal successes, challenges, and sources of inspiration or support in STEM. We then formed profiles of each woman identified in the texts using her multiple narrative pieces.

3.1.2 Interviews

We conducted interviews to gather a limited but in-depth set of contemporary, discipline-specific experiences and viewpoints that may not have been represented in the extant texts. The interviews were semi-structured and open-ended, with approximately ten broad questions that asked the participants to describe their academic background, their current academic or work situation, a challenging time and how they overcame it, feelings of acceptance in their field, aspirations for the future, and advice for institutions and individuals. We had 8 interviews in-hand, conducted between 1998 and 2005, with two women of color. We conducted follow-up interviews with each of them and collected 9 additional interviews, conducted between 2010 and 2012, with seven women of color. In total, we had 19 interviews from nine women of color. The majority of interviews were conducted over the phone, but in a few cases, the interviews were conducted in person at STEM conferences or at the participants' school or workplace. Interviews lasted approximately 1.5 hours, were audio-recorded, and were later transcribed. We aimed to have a purposive sample that included women who were Black, Asian American, Latina, and Native American, as well as women who represented all career stages. We selected participants for our purposive sample that were recommended to us through broad personal and professional networks, and via widely distributed email solicitations to professional organizations for women or minorities in STEM.

3.2 Data Analysis

Riessman (2004, 2007) states that *narrative analysis*, a method of seeing beyond individual life stories to broader patterns, is especially effective for understanding the experiences of those who are traditionally marginalized. Prior to beginning our study, we noted that most of the current knowledge base about women of color in STEM—hundreds of written pieces—existed in narrative form and was scattered in various places. We used narrative analysis in order to respect the stories as *data*, thus detecting themes (e.g., mentoring, peer support, research experiences) within and across those stories.

For our study, narrative analysis required transparent processes of laying out stories, identifying codes, entering codes into a matrix, then inductively creating conceptual groupings and orderings from the data. Identifying codes required that we organized the material into segments of text before bringing meaning to the information. Building categories of themes from the bottom up (see Creswell, 2009), we coded and discussed until we established a comprehensive set of themes. Our procedures included intercoder agreement to see whether two or more coders agreed on codes used for the same passages in the text (Creswell, 2009). Coding pairs were responsible for coming to an agreement on codes for their assigned narratives. Additionally, the entire team regularly coded calibration articles together to ensure that all members were applying emergent codes in similar manners. Through these meetings, we continually refined our codes. Each person was then assigned a set of related codes to detect emerging themes. Team members exchanged their work with one another, and everyone then analyzed the themes to affirm or reconstruct the themes. The final themes are presented below as eight agentic strategies for persisting and flourishing in STEM.

3.3 Reliability and Validity of Methods

Our reliability procedures included checking our transcripts to correct obvious errors, deriving new codes independently before cross-checking with other team members, and taking detailed notes during calibration meetings on any changes to definitions of codes and providing examples in the codebook (see Creswell, 2009). Our validity strategies included triangulating different sources of information to build profiles of the women we studied via extant texts; finding convergence between different researchers' ideas of codes and themes; presenting in this paper the few discrepant pieces of information we found in our findings; and utilizing peer debriefing, that is, sharing our findings with and receiving feedback from our colleagues outside of the field, who provided feedback (see Creswell, 2009). All of these methods aided to ensure against bias as much as possible.

4. FINDINGS

This report focuses on the navigational strategies that 22 women of color in our study took to advance in physics and astronomy. While many of the women's narratives described the various ways in which they succeeded in STEM, with help from others and through self-supporting strategies, their narratives also depicted isolating science environments like those identified in other literature (e.g., Brown, 2000b; Brown, 2000a; Carlone and Johnson, 2007; D. Johnson, 2007; Joseph, 2012; Justin-Johnson, 2004; MacLachlan, 2006; Ong, 2005; Ong et al., 2011; Shain, 2002; Tate and Linn, 2005). Similar to findings in the literature, our participants reported a lack of connection to and support from their peers, faculty, and supervisors. Laura,[3] a Latina physicist, illustrated this isolation by comparing her disconnect from colleagues to her disconnect from a room full of football players.

> *The work environment. It's really tough. We need more women… Now imagine yourself… Who is the person who would be most… hard to communicate with? Let's say, I don't know, a football player.... Somebody that's really in another world compared to the world that you are [in]. And if you sit alone in that room, the two of you, it would be almost hard for you to have to talk… with this person. Now, consider a room full of them, and you're the only one that's you… And they're really not making any effort to get me in their conversation. And… there isn't any other conversation I could have with them. [sighs] So, that's how you are all the time in physics.*

Although many women in our study were faced with similar feelings of isolation and lack of connection, they found ways to succeed and persist. They did not passively accept these circum-

[3]Interviewees are represented by first-name-only pseudonyms.

stances. Instead, they took action in forming the paths to their careers via specific navigational strategies. The strategies used included the following:

- seeking an environment that enabled success
- circumventing unsupportive advisors
- combating isolation using peer networks
- consciously demonstrating abilities to counteract doubt
- finding safe spaces for whole selves
- getting out to stay in STEM
- remembering their passion for science
- engaging in activism

4.1 Seeking an Environment that Enabled Success

Our analysis revealed that some women of color entering physics and astronomy were aware of the barriers they would face due to their race and/or gender, and they proactively pursued a program or work environment that would support their success. This meant looking not only for good science content and practice, but also for supportive attitudes toward women and underrepresented minorities.

Adrienne Stiff-Roberts ,[4] a Black professor of applied physics, explained how she "has had her share of struggles in a field dominated by White men… been 'second-guessed' more often than her White counterparts and has dealt with issues they haven't had to face." Because of this, she always chose to go to places where she has had a support system, and as a result, had doors opened for her. Some women investigated, prior to enrollment in their graduate programs, the climates of departments and attitudes of potential advisors and peers. Nina, an Asian American first-year graduate student in astronomy and astrophysics, explained that in her graduate school search, issues such as school climate, support from advisors, and support on gender issues were as important to her as science educational opportunities. She gleaned information on these issues by speaking with current students:

> *When I visited and I talked to [a potential advisor's] graduate students, they actually warned me away from him. They told me that it's very stressful working for him, because he was very stingy with his money and would make his students pay out of their own pocket to go to conferences and stuff. And sometimes he wouldn't credit his students' work. And his male students actually told me that it happened more frequently with his female students. And as much as this guy has done, and as much as I wanted to try theory, I honestly just don't want to put up with crap like that. That's not why I'm in grad school.*

Nina's proactive tactic allowed her to avoid working with a potentially unsupportive advisor. Teresa Segura, a Latina planetary scientist working in industry, also displayed intention in choosing her advisor, whom she said she chose "specifically because he kind of reminded me of

[4]Subjects from extant texts—public documents—are referred to by their real names. A full reference list of the extant texts can be found at http://www.terc.edu/display/Library/Extant+text+references+for+Narratives+of+the+Double+Bind

me in that he was trying a bunch of different things and had his finger in a lot of different pots."

In addition to carefully selecting suitable advisors, others like Nina examined overall numbers of women and minorities in, and the climates of, departments and institutions. After receiving a master's degree in physics, Jami Valentine, a Black woman, chose a different institution for her physics Ph.D. degree, seeking greater numbers of minorities and women. At the new institution, she found "a better sense of community," as well as two female professors and about 30 female graduate students in the physics department. (Her prior institution had no female professors and only 10 female graduate students.) Laura wanted an environment with a good track record of treating women fairly when she was looking at graduate schools, and she described her deliberate online search for departments with successful women professors on staff. Unfortunately, this tactic was not fail-proof. After enrolling, Laura discovered that the website was outdated, and in fact, no female professors worked there. Our research found other narratives in which incorrect information led to women selecting less supportive programs than they had originally been seeking.

This strategy was not exclusive to the finding of schools. Some participants recognized that the work schedules and lifestyles common to academic jobs in physics and astronomy posed a challenge to work-life balance issues such as starting a family (Ko et al., 2012), so they intentionally sought positions within STEM, but outside of academia. When we interviewed Kristen, a Black postdoctoral fellow in physics and astronomy, she was engaged in a job search. Seeking a position that would allow her to have a more manageable work schedule, she expressed interest in industry over academic jobs, because the hours would be "more nine-to-five" and "that job would be the end job." Similarly, Allison, a Black woman in her early career who studied astronomy and astrophysics, felt dissociated with the long hours of academia and feared the lack of work-life balance. Therefore, she explored other options before completing her Ph.D. and selected a research job with the government.

The strategy of seeking environments that enabled success deterred resentment related to work-life balance issues and revealed a high level of selectivity among women of color who persisted in physics and astronomy. It demonstrated planning in their selection processes and advanced awareness of the barriers to expect in traditional STEM climates. Contrary to any model of women of color in STEM as passive victims of their environments, this strategy pointed to the use of personal agency to bypass obstacles rooted in gender and/or race.

4.2 Circumventing Unsupportive Advisors

Traditionally, advisors in STEM programs hold sway over many areas of student experience, including research focus, how much time is spent in the lab, professional development and networking opportunities, and length of time until graduation (MacLachlan, 2006). Power dynamics between student and advisor may be exacerbated when there is also a power differential based on race and/or gender, as is commonly experienced by women of color in STEM fields where advisors are most frequently White and male (Brown, 1995; Carlone and Johnson, 2007; MacLachlan, 2006; Solórzano, 1995a,b). Consistent with the literature cited above, many women in this study reported strained relationships with their advisors. Problems ranged from lacking a connection, to feeling misunderstood, to being ignored, to actively being undermined. They also reported a common strategy of circumventing unsupportive advisors.

Denise, a Black professor with a Ph.D. in astronomy and astrophysics, described her graduate advisor's day-to-day behavior as "benign neglect." Denise's tactic was to build a strong committee to fill in the gaps in support left by the advisor. The advisor, who had originally promised Denise she would be able to finish requirements for graduation faster than typical students, thus enabling her to move on to the next step in her career, reneged on his promise. In response, Denise went to her committee to demonstrate her adequate fulfillment of requirements and promptly graduated.

Another significant method of circumvention described by participants was to distinguish ineffective or undermining advice from those recommendations that were truly helpful—especially in matters relating to gender, physical appearance, or level of competency. For example, Anna Coble, a Black biophysics professor, returned to school after several years of teaching. Her advisor recommended a smaller course load, believing Anna would not be accustomed to the work. Knowing her own competencies and preferences, Anna explained that she did not allow her advisor's concerns to alter her course schedule or delay her graduation. Likewise, Ariana, a Black researcher with a Ph.D. in physics, received advice from her postdoctoral advisor on how to dress more androgynously to fit in with her male peers. Although she appreciated the concern, Ariana simply pointed out that her body structure would never allow her to look androgynous.

Diana Garcia Prichard, a Latina physical chemistry professional and mother of two, evaluated the advice of advisors and professors by determining whether she respected the person giving the advice.

> *I had one professor tell me that the reason family values in this country are falling apart was because of people like me who were in graduate school, instead of at home taking care of their kids. Being an older student, I recognized that I really didn't respect the person saying those things anyway, so I disregarded his comments. It's important to learn to make that distinction.*

Likewise, Luz Martinez-Miranda, a Latina physics and engineering professor, was told by a professor that she "was wasting the federal government's money" by being in graduate school. She related that she resolved not to let the discrimination affect her and that it made her even more determined to succeed as a woman of color physicist. Such tactics relate to what Carlone and Johnson (2007) described as "redefining meaningful others." The authors discussed how it could be valuable for some women of color in science to turn away from established members of the scientific community as sources of recognition and instead look toward their families, communities, and other people of color for affirmation, particularly when members of the science community were being unsupportive. Correspondingly, we saw some women in our study devaluing the advice of their advisors, traditional holders of power in STEM programs, and locating support elsewhere, particularly in peer networks.

4.3 Combating Isolation with Peer Networks

Our study noted that a common reaction to a lack of support in STEM environments is the defeatist activity of self-isolation, including doing homework and studying for tests alone. Some of the women in our study recognized that this self-isolation was not serving them, and when they did not find support in the traditional structures of their departments, they employed a strategy of identifying, recruiting, and organizing peers who could support them. Participants reported that such peer networks were extremely useful in helping them navigate their physics or astronomy environments.

Nina described how helpful it was to collaborate with peers with complementary skill sets and related how a tactical choice of her labmate helped her advance in one of her undergraduate classes:

> *I had a lot of trouble in the beginning with that [physics lab]... I had picked [my labmate] because I knew that she was really comfortable in lab, and she was really good at programming and analyzing data. And I am really, really good at giving presentations... and she was very nervous and not sure of how to pull together information in a way that was a visual and intellectual argument to get your point across. So we had complementary skill sets.*

Nina also described building a network that she could turn to for help with schoolwork and graduate school applications as an undergraduate, but that became supportive in many other areas as well. These peers helped one another not only with their science careers, but also with personal concerns. Nina felt consoled by speaking openly with others who had doubts like she had about her scientific abilities:

> *We had evolved into a group that would meet up once or twice a month... And so, we became very open about issues, like… doubts we had about ourselves in science. And realizing that all these people I really admired also doubted themselves was good. It kind of made me realize that I might feel stupid, but it's not that I'm stupid—everyone goes through this.*

During her first year of graduate school, Allison initially tried to navigate a difficult class by herself, not realizing that other students were also struggling. She finally saw this as a mistake and talked to another classmate whom she came to realize was having the same issue. They decided to become "hardcore study buddies," and not just for that class, but through to their qualifying exams. Like Nina, Allison had found a classmate that complemented her by excelling where she struggled and vice versa. While Laura had a challenging time relating socially to her male peers, she made herself become the catalyst for the formation of study groups in school. She explained that being proactive in forming relationships with those peers was essential for her success.

In a context in which students feel isolated and encounter racial and/or gendered incidents, we found that avoiding the learning environment and limiting interactions with peers was not uncommon. However, we found that the conscious building of peer networks appeared to be an alternate and successful strategy for reducing isolation. These networks crossed race/gender boundaries and were formed with intention, demonstrating an agentic response to existing gaps in students' support systems.

4.4 Consciously Demonstrating Abilities to Counteract Doubt

Doubt is a common experience of women of color in STEM departments. Previous studies (Brown, 2000a; Carlone and Johnson, 2007; Joseph, 2007; MacLachlan, 2006; Ong, 2005) have documented women of color reporting that they were often doubted by their peers and professors, and sometimes as a result, they doubted themselves. Women in our study also reported being doubted by others and expressed doubt in themselves at times. Luz Martinez-Miranda described the detrimental effects of doubt upon her experiences at MIT after she transferred there from the University of Puerto Rico:

> *Although I was born an "American," as a female minority student I always had the feeling that my male professors were doubtful of my abilities. There never seemed to be any question that my male classmates could do the work. However, given the ste-*

reotype that Puerto Ricans are "lazy," I felt that I had to prove myself all over again. This was terribly frustrating because I had already proven that I could do the work back home!

In response to similar experiences of feeling doubted, participants in our study adopted a strategy of purposefully demonstrating their abilities to themselves and to others in order to counteract their tendency to look and feel less self-assured than some of their peers. While an undergraduate, Elena, a Latina researcher in physics, had previously prefaced her statements with "I think," which resulted in her assertions being taken as opinions, whereas her male peers typically spoke in a factual manner. Her experience agrees with several studies have found that women in STEM classrooms speak with less confidence than men (e.g., Brainard and Carlin, 1998; Etzkowitz et al., 2000; McDowell et al., 2006). Elena decided that a conscious change was necessary to survival in her field:

The way I learned from my male classmates was like: don't even say, "This is the way I thought."[Instead say,] "This is the way it is…" I learned some of it, because to me, it was a survival mechanism… [Now] I wouldn't dare give a presentation on any paper that I worked on and say, "… I'm not quite sure about this result... [or] I have more of a communal understanding of this subject." (Originally cited in Ong, 2005)

By consciously changing her speech pattern, Elena was able to present herself to her peers with more confidence. Laura also focused on her communication style as a means of preempting work colleagues who might second-guess her. She explained that she would clearly communicate her work purpose and plans in order to appear sure of herself. In addition, she displayed her Ph.D. credential in her email signature to preclude anyone from discounting her authority. Likewise, to disprove doubt from her classmates, as well as to combat isolation, Shirley Ann Jackson, now a renowned physicist and the first woman and Black president of Rensselaer Polytechnic Institute, openly displayed the graded coversheets on her problem sets in her undergraduate courses to earn the respect of her peers and in hopes that they would talk with her more.

While some used the aforementioned tactics to appear more confident to others, Nina used a different means to boost confidence in her own eyes:

One of the other things I do when I'm doubting myself is I'll apply to fellowships. Because, when you apply to a fellowship, your personal statement is pretty much an argument for why you're so awesome. And it's just a good reminder of why you can do things… Being at [top science schools], it's easy to... not realize that you're doing good work, because everyone else around you is doing such awesome work.

By writing out her abilities and accomplishments, Nina was able to maintain confidence in herself as a scientist, rather than give into doubts about her ability from herself and others. Like others in our study, she took action, giving a conscious demonstration of her abilities in order to change how she was perceived.

4.5 Finding Safe Spaces for Whole Selves

Many STEM departments and workplaces are not spaces in which multiple identities (female, racial/ethnic minority, and scientist) are welcome (Ong, 2005). Some participants in our study went elsewhere to engage with groups and events where they felt safe to express their "whole" selves, and thus did not have to fragment or hide racial or gendered aspects of their identities. For example, professional societies and school organizations, especially those dedicated to minorities or women in STEM, served as both learning environments and safe havens for these women of color. Such organizations allowed participants to openly express both their science identities and their racial/gender identities simultaneously. Participants described contexts in which they could share experiences of discrimination without fear of retribution or doubt, and vitally, share their mutual love of science.

For Chloe, a Black student who recently received her Ph.D. and studied physics and astronomy, the National Society of Black Physicists was a place where she did not have to be concerned about whether any aspects of her identity would be questioned. Attending their annual conferences throughout graduate school, she felt comfortable being her whole self among her colleagues.

> *I could sit down and talk with people about physics and then cross over to talking about some stupid thing somebody had said to me about like, Black people, and not have someone in the room go, "But are you sure that was racist?"… That it was a safe space where I can actually be a person of color and be a physicist at the same time and not have anyone question my commitment to either identity… the impact on me has been phenomenal.*

Events that sought to gather women, minorities, or women of color scientists were especially valuable because, as Nina explained, they concentrated all potential role models in one place and made it possible to interact with them. Nina sought out successful female scientists and asked them about work-life balance issues, such as how they managed to have a family at the same time as pursuing a career in science. Kristen, who considers work-life balance issues to be the main stress in her life, spent a lot of time talking with "a couple of [her] women postdoc friends who [were] in the same boat about what to do about it." Additionally, she sought out conversation with her friends at the women's center that she helped found during her master's program. Jami Valentine noted that her graduate school institution's "diverse scientific environment provided her with the support she needed." She also maintained a database of minority women physicists and spoke about how she attended an international conference on women in physics, in hopes of working with minority women in her future career. Allison explained how being part of two student groups for women or minorities in science and engineering at her graduate school institution widened her network to include other students like herself, whom she would not have met otherwise:

> *I became part of [the societies] because I did find them to be very interesting, and that's actually how I met some of my other friends who were in similar fields, and I got to know that there are a large amount of minority students. It was encouraging… I was glad that I went to some of their meetings, so that I could see just how many there were… That knowledge was a form of support.*

When it was not possible to find scientists who carried one or more of their racial and gender identities, women of color sought connections with underrepresented peers outside of their academic fields. Shirley Ann Jackson, for instance, joined a Black sorority in which she made some close friends and had more opportunities to socialize than she had with her physics classmates.

Participants indicated that these extra-departmental activities supported them to persist in their unwelcoming programs or workplaces by decreasing feelings of isolation and connecting them with those with like experiences. In the next subsection, we discuss other ways in which women of color have stepped outside of their departments in order to find the resources to persist in their fields.

4.6 Getting Out to Stay in STEM

When women of color were not able to find safe spaces that accommodated their full identities, some participants in our study temporarily left their departments for ones in which they felt more comfortable. For example, both Kristen and Laura took respite from the climates of their scientific programs by studying abroad. Such "getting out" by leaving the country ultimately provided the impetus for each to become happier in her work and complete her degree. Kristen remedied her frustration with her own graduate institution by seeking out new collaborators overseas. She described the semester she spent abroad and its impact on her:

> *I organized a few semesters abroad, sort of to work with other people who I felt were… more specialists in our area. And a couple of those were really good experiences. I think that sort of helped increased my happiness at what I was doing. So I suppose things that I did to cope were to find outside collaborators and organize semesters to go and work with them. That helped a lot—scientifically and also personally.*

By temporarily leaving her current situation, Kristen was able to restore her satisfaction with her work—something that she noted benefited her on multiple levels. Similarly, Laura was ready to quit her Ph.D. program by the end of her third year, convinced that she did not want to work towards a career with seemingly endless workdays. Then she accepted a two-semester position in Europe, where she truly enjoyed the science work and, equally importantly, witnessed male and female scientists leaving work by 6 p.m. She decided to continue pursuing her degree and to model her future work life after that of her European colleagues (which, years later as a professional scientist, she successfully did).

Our study also found participants doing some "getting out" while staying in their home programs. In American STEM, particularly among academics, there is a common perception that scientists, in their single-minded pursuit of truth, must work well beyond the typical eight-hour workday (AstroBetter, 2012; Ceci and Williams, 2010). It is a often an explicit expectation for scientists to put in long days, and sometimes long nights (Jones, 2012) and the unspoken expectation for the STEM worker is to do science all the time—to the neglect of family, social life, and personal well-being (AstroBetter, 2012; Ceci and Williams, 2010). Among our participants, we have found that career-life balance issues for women of color may differ from those of White and/or male peers, negatively impacting retention and advancement in their STEM careers (Kachchaf et al., 2014).

However, several narratives in this study revealed that rejecting this "all STEM, all the time" attitude enabled women of color to persist longer and more happily in their physics and astronomy environments. Taking breaks from their scientific work or distracting themselves from thinking about science allowed women of color to better tolerate their departmental cultures. For instance, Denise explained how she pursued travel and multiple hobbies during her Ph.D. program in order to bear the environment she was in:

> *I can't live in this environment and be happy... I traveled a lot. I learned how to do Indonesian dancing... I did African dance. I learned how to belly dance… I got certified in massage and acupuncture… Because they were things that made being under these conditions tolerable… The same week I got my Ph.D., I got my massage certification. I got massaged every week while I was in this hellish environment.*

By finding activities that she enjoyed outside of science, Denise was able to distract herself from her graduate program's "hellish environment" that she described as "racist," in order to persist to the completion of her doctorate. She succeeded because of, not despite, time devoted to activities outside of astronomy. Other participants revealed non-science activities that made the stresses of their programs more tolerable. Nina explained that she joined a choir at her graduate institution, because it allowed her to pause her science thinking and use a different part of her brain for three hours a week. Chloe revealed that a great deal of (non-scientific) reading for pleasure was a form of respite for her from her extremely unsupportive environment. Luz Martinez-Miranda, who holds degrees in physics and music performance, explained the value of having a non-science interest:

> *I've spent most of my life playing the piano. In fact, I received my bachelor's degree in music [and physics] while at the University of Puerto Rico… I know for me, having another interest was nice because it got my head out of just doing science-related studies. I don't believe that one's life can always be about work!*

Activities such as traveling, dancing, singing, reading fiction, playing music, or learning a new hobby gained more significance when they impacted science identity. The women in our study were aware that their outside interests could mark them as less committed to science, yet they still chose self-supporting, non-science activities that sustained their identities as scientists by enabling them to persist in their work under challenging circumstances.

4.7 Remembering Their Passion for Science

Above all else—in the face of difficult and exhausting STEM environments—we found that passion was a consistent, compelling motivator for persistence in science. Many women in our study powerfully described their passion for science and how remembering their love for it allowed them to endure the many intellectual, social, and cultural challenges they faced. Nina articulated that science was hard and reflected on her effort to remember why it was beautiful:

> *With astronomy there is a lot of day-to-day grunge work, a lot of debugging, a lot of reducing data. And so, when I get frustrated or tired… I just pull up my old data, the original data. And I am back to staring at stars and planets in some photograph, in some corner, in some point in time in the universe. So, being able to have that child-like and very idealistic filter, I think, is crucial, because [science is] hard. And I think the thing that makes it worth it is remembering what's so beautiful about what you're doing.*

Denise gave a similarly moving account of how she experienced science and displayed how her view of the overall magic of science drove her to pursue her fields even during disheartening times:

> *I do have a love of a night sky… I'm not a depressive person. But at the times that I felt the lowest, I've gone and looked out my window and a shooting star will go by. The sky has much meaning for me… Sometimes, the night sky absolutely frightens me, and sometimes it's like an old friend… I spend an enormous amount of time, in middle of the night… looking up and seeing what's going on.*

Comparably, Elena explained how she used her heart's passion to fight her mind's logic that she would be happier if she left STEM:

> *In physics, as a woman of color, you will not find the way paved… You walk into a stranger's territory, people look at you, you look and perceive yourself to be different, you are walking the narrow path… much will be asked of you, much will be expected*

> *of you… You will be asked to draw from your internal self… No other part of you knows your soul better than your heart. Your mind gets confused, it tells you that the 'exit' is just next door, why don't you take it? All the suffering will end, you will finally be happy! ... But your mind does not know your heart, it does not know your passion.*

Likewise, Laura related that science was an extremely difficult path, both intellectually and emotionally for her as a woman of color, but that it was worth pursuing because it was the most inspiring field to her. Imagining a hypothetical situation in which she could go back and choose a different career path, she expressed how her love of physics would still trump any challenges:

> *There's no other thing that I would want to do rather than physics. So from that point of view… I [would] choose it [for] myself again.* And even with the knowledge that I have today, of how hard it is to constantly have to prove yourself… I would still probably choose it today. Just because I can't think of a better alternative, or something that I would rather do, rather than this.

In Laura's and others' narratives, we found a strong theme that the beauty and coolness of science was worth facing and overcoming the challenges of STEM culture. In fact, for many participants, their sense of science being "worth it" was so significant that, rather than regretting their choices or wanting to deter other minority girls and women from the STEM experience, they had a desire to share their passion for their discipline. One way this occurred was through participation in activism to diversify STEM.

4.8 Engaging in Activism[5]

Over half the women in our study reported participating in some kind of activism, what the *Beyond the Double Bind* project defined as "STEM-related volunteer work." Engaging in activism was a strategy employed by some, largely as a way to help others after them pursue science, but sometimes also as way to help themselves in the process. For example, Shirley Ann Jackson worked tirelessly to promote minorities at her undergraduate and graduate school institution, where she felt completely isolated:

> *[What has been] described as Jackson's "trademark combination of self-help and help for others," may account for her decision to stay at MIT, where she had already been active in urging the university to admit more minorities.*

Similarly, Baez (2000) found that activism functioned not only as a motivation for women of color to persist in their fields but also served as a way for them to change their existing departmental cultures. Ceglie (2011) also found that women of color's identities in STEM included giving back to their communities.

Many in our study displayed interest in increasing diversity in STEM. They described various tactics to reach two audiences: authority figures—including institutional department heads, academic research communities, national committees, policy makers, and other professionals—and the specific populations they were trying to affect—women, minorities, or women of color. Ariana conducted educational research; Hattie Carwell, a Black physicist in industry, chaired a scholarship fund for Black students; Chloe worked to have antidiscrimination policy enforced; and several women served on national committees promoting women, minorities, and women of

[5]Portions of this section appeared in Ko et al. (2012).

color in physics, or STEM in general. The women also participated in projects aimed at reaching the general public: Denise participated in documentaries about minority scientists; Beth Brown, a Black astrophysicist who worked for NASA, was involved in educational outreach; and Hattie Carwell documented the achievements of Black scientists in a published volume.

Participants also reported doing direct outreach via teaching, mentoring, and recruitment and retention efforts. They became role models and mentors, and they participated in and founded programs in their communities and institutions to provide opportunities to students, peers, and colleagues. Diana Garcia-Prichard encouraged high school girls to explore non-traditional careers and to get hands-on physics experience. Luz Martinez-Miranda worked in a program at a local university to encourage students, especially minority females, to explore science and engineering:

> *Currently, I'm also involved with a program… that encourages K-12 students to explore areas of science and engineering. I believe that by being a minority woman, I am providing a role model for the students I've encountered, especially the girls. Teenage girls have the misconception that being a female scientist will prevent them from having a social life. This isn't true!*

Activism activities were often motivated by experiences of race, gender, or both. Kristen described experiencing internal pressures to persist and succeed in science in order to act as a role model for all the girls or minorities, including family members, who will come after her:

> *I have three younger siblings, I always felt like I should [be a role model]... I feel like, "Oh okay, well I'm a woman of color in science and women of color in science, there aren't very many... I should do my part and keep going…" Nobody's ever said, "You can't quit because," but I definitely do [feel a responsibility to the community].*

Chloe described a similar pressure and also discussed a program at her school for which she volunteered. She expressed enthusiasm for her groups having mostly minority females:

> *[B]ecause I'm always either one of only two female mentors that they can choose from... I had two students from [where] my family's from... So for me, it was really, really exciting to have these young women of Caribbean origin in my group.*

Activism led to rewarding feelings and experiences, whether through good results in witnessing young students advance in STEM, or through being looked up to as scientists. Chloe described hearing from a former participant in her mentoring program, a young woman of color who had been insecure about her math and science skills:

> *She came into the group and was like, "You know, I am not very good at math. I haven't had as much math as everybody in the group. And I don't think I'm smart enough to be a physicist, so I'm planning to do a bunch of physics classes, but I'm going to get a degree in biology and apply to medical school." And I was like, "Look, if physics is what you're interested in, then you can do it." And I was thrilled out of my mind when she emailed me a year and a half ago, and said, "So what do you think of [School Name]'s mathematical physics program? Because I was just admitted to it."*

Chloe also described how, during times of self-doubt, activism boosted her confidence in her abilities. About volunteering to teach young students, she said, "It's actually very heartening when you realize, 'Well, at least somebody in the room thinks I know what I'm talking about.'" Other personal reasons behind activism included feeling at home with fellow activists and reconciling personal values and work goals. Of her collaborations with fellow physics educators, Ariana explained, “We thought that not only we had found sort of our personal tribe, but we had found a way to bring personal issues that we cared about into the core of our work.”

Overall, it appeared that activism carried deep and multiple meanings for the many women of color in physics and astronomy who took part in it. The breadth of participation and the benefits described lead us to believe that it had an important role as a navigational strategy for persistence, serving as a significant form of motivation, hope, and encouragement. Because activism was usually not rewarded with promotion or tenure (see Baez, 2000), time and energy spent by participants in improving science environments did not necessarily assist in career advancement. Despite the real and perceived consequences to their careers, several women of color expressed the value of their activism and said they would choose to do it again.

5. DISCUSSION AND CONCLUSION

We have brought into sharp focus the strategies used by women of color in physics and astronomy for continued participation and success—and how they must use these strategies because their racial and gendered identities result in social and academic isolation in their STEM environments. Across the many narratives we studied, women of color shared similar concerns about isolation and exclusion, and they adopted an assortment of tactics from a similar set of navigational strategies which included seeking an environment that enabled success; circumventing unsupportive advisors; combating isolation with peer networks; consciously demonstrating abilities to counteract doubt; finding safe spaces for whole selves; getting out to stay in STEM; remembering their passion for science; and engaging in activism in order to change the future STEM culture. The enormous time and energy invested in these strategies for persistence and survival could have been invested in *doing science*. Physics and astronomy departments and workplaces should be deeply troubled by this potential loss of creativity, collaboration, and productivity. Thus, they should seek to improve their institutional cultures to be more welcoming and inclusive of all students bearing various racial or gender identities.

From our findings, we have drawn recommendations for two groups: women of color who seek to succeed in physics, astronomy, and other STEM fields; and institutions of higher education and employers dedicated to retaining women of color and broadening participation in STEM.

5.1 Advice for Women of Color in STEM

Our findings illuminate that, even though women of color may feel isolated in their efforts to pursue science, they share many experiences and strategies in common with one another. While it is unfair to put the burden fully on individuals to persist in STEM, institutional reform moves very slowly. Thus the agentic tactics recommended below may prove helpful in the meantime:

- Do your research before applying to a school, postdoctoral fellowship, or job. Interview students or employees at your programs of interest. Review public information to ensure that the department or company has values similar to your own and that you will be treated equitably. Inquire about workloads and schedules for a healthy work-life balance.
- Learn how to negotiate advisors’ or supervisors’ expectations about your workload and length of time until graduation or promotion. Critically examine their advice and

motivations. Consider whether you respect the person providing this advice and recognize that while advice may be well-intentioned, solutions are rarely one-size-fits-all.

- Combat isolation by proactively building a strong peer network that can provide you with support on science content and navigation of the climate. Look for peers with skill sets complementary to your own, as well as those who will provide consistent, strong emotional support.
- *Perform* competence. Put aside modesty and put forward your strengths and achievements to your STEM peers, leaders, and yourself.
- Seek out school organizations or professional societies where you can express other identities, or better yet, multiple aspects of your identity at once. This may include groups for women and/or minorities in or out of STEM but also other identities, such as sexual orientation or religion.
- Look outside of STEM for relief from the daily grind. Pursue a hobby, sport, or other activity that you find enjoyable, so that you may be more focused and productive when you re-engage with your STEM work.
- When external resources do not prove to be enough, look internally for motivation. Remember your love for science and the reasons you decided to pursue a STEM career.
- Participate in activism to encourage others like you to pursue and be successful in STEM. In turn, this work will help you feel less isolated and may uplift you in your environment.

5.2 Advice for STEM Departments and Organizations

Many forward-thinking schools and workplaces have already instituted support programs for women *or* minorities, but most of these programs do not presently address the specific needs of women of color, who exist at the intersection of these groups. By exploring the navigational strategies of women of color, leaders can identify unaddressed needs and begin to create institutional supports to fill those gaps. We offer the recommendations below, drawn from our findings, as a starting point for reform:

- Recruit and retain more women of color students, faculty, and employees at all levels. Feature these members on your website and in publicity. Their presence will attract more women and minorities to your discipline and organization.
- Hold mandatory cultural awareness trainings for advisors and supervisors to prevent implicit bias and (conscious or unconscious) improper behavior. Promote the creation of and participation in a diversity committee whose goal is to advance policies on diversity issues.
- Promote the creation of and participation in mentoring networks among students, faculty, and employees. Strive to offer minority women more than one mentor or network, as people with different expertise can offer support in different ways.
- Foster a class environment where all students participate freely and equally. Affirm students' STEM abilities to help them increase confidence in themselves.
- Keep women of color updated on opportunities to participate in campus, regional, and national organizations and events targeted to underrepresented members, especially those for women of color in STEM. Support them in these activities.

- Promote outside-of-STEM activities. Model more balanced lifestyles for students and employees. Create human resource policies that allow for non-STEM time in their lives and flexibility in work schedules.
- Support women of color in STEM as they work to diversify their fields. Incorporate opportunities for STEM-related volunteer work. Eliminate career-advancement penalties for time spent on volunteerism; better yet, add it as a criterion toward promotion.

We applaud the women of color in our study for advancing in their science careers despite adverse circumstances, and we elucidate how they were not passive victims of departmental cultures. They exercised agency and were active in the outcomes of their science pathways; however, relying on individuals to adjust their actions and behaviors in order to survive existing science climates is not a long-term solution to recruitment and retention of women of color. For institutions committed to broadening participation in STEM and strengthening the quality of science through diversity (National Research Council, 2011; Page, 2007; Spencer and Dawes, 2009), implementing the above recommendations can help alleviate the isolation crisis that is experienced almost universally by women of color in STEM. When experiences of isolation are replaced by experiences of equality, welcome, and collaboration, we will begin to see many more minority women in the scientific ranks.

6. LIMITATIONS OF THE STUDY

Limitations of this study include a racial imbalance among the participants studied; that is, 59.1% of women in our study are Black vs other races (see Table 1). This disproportion occurs for several reasons: a racial imbalance within the existing extant texts; a racial imbalance amongst the current representation within the fields of physics and astronomy; and the limitations of our research team in recruiting more Native Americans and Asian Americans to our study. There are also inherent limitations in the use of extant texts (Riessman, 2004). For example, we could not ensure that the interviewees in the texts were asked a broad range of questions, nor could we control for the depth or complexity of information provided. Further, we were aware that most of the materials were not written for research purposes but rather for goals such as empowerment, education, or promotion of the participant's employer. Nonetheless, we found the data in the texts to be sufficiently rich for inclusion in the analysis. Additionally, our study was affected by self-selection bias; those who opted to participate likely do not represent the entire target population of women of color in physics and astronomy.

ACKNOWLEDGMENTS

We are grateful to Jodut Hashmi, Irene Liefshitz, and Carol Wright for their dedication and help in coding and organizing the data. We are also very thankful to Jodi Asbell-Clarke, Sandra Begay-Campbell, Theda Daniels-Race, Lorelle Espinosa, Patricia Gándara, Sylvia Hurtado, Angela Johnson, Tamara Ledley, Abigail Levy, Wendy Luttrell, Shirley Malcom, John Matsui, Gary Orfield, Roli Varma, and Barbara Whitten for supporting us in the overall project and for providing feedback on earlier drafts of this paper and helping in its development. Jaqui Falkenheim of the National Center for Science and Engineering Statistics at the NSF vitally aided us in locating data on women of color in STEM. Jennifer Haley critically helped in the final stages of writing. This material is based upon work supported by the National Science Foundation under Grant No. NSF-DRL 0909762. 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 National Science Foundation.

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JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 37, NO. 7, PP. 629–654 (2000)

African American College Students Excelling in the Sciences: College and Postcollege Outcomes in the Meyerhoff Scholars Program

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Received 19 January 1999; accepted 3 January 2000

Abstract: This paper describes and assesses the effectiveness of the Meyerhoff Scholars Program at the University of Maryland, Baltimore County (UMBC). The Program is designed to increase the number of underrepresented minorities who pursue graduate and professional degrees in science and engineering. Until 1996 the program admitted African American students exclusively, and the current study focuses only on students from that group. The Meyerhoff students have achieved higher grade point averages, graduated in science and engineering at higher rates, and gained admittance to graduate schools at higher rates than multiple current and historical comparison samples. Student survey and interview data revealed that a number of program components were viewed as being especially important contributors to students' academic success: Program Community, Study Groups, Summer Bridge Program, Financial Support, Program Staff, and Research Internships and Mentors.© 2000 John Wiley & Sons, Inc. J Res Sci Teach 37: 629–654, 2000

In a world increasingly driven by technology, living the American Dream requires more advanced education than ever. Literacy and skills in science and technology are becoming increasingly important; in fact, our economy's future appears tied, at least in part, to the strength of a technology-based workforce. More than three decades ago, the United States Government made a commitment to help African Americans achieve educational parity with the White majority. Although the commitment remains intact, the goal remains unattained (National Task Force on Minority High Achievement, 1999).

In 1986, only 1.1% of American citizens receiving doctorates in science, engineering, and mathematics (SEM) were African Americans, even though African Americans represent 12% of the United States population. In 1992, the percentage receiving SEM doctorates was 1.2%, and by 1995 it had increased to only 2.0% (NSF, 1996a, 1996b), despite the fact that proportionately higher numbers of African Americans aspire initially to science graduate degrees than do Caucasians (Elliott, Strenta, Adair, Matier, & Scott, 1995).

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The Process of Leaving Science Majors

Minority students cannot earn graduate SEM degrees if they do not first achieve and persist in these disciplines at the undergraduate level. The process underlying achievement and persistence in SEM, which begins in the first semesters of college, has been investigated by a number of researchers. Many freshmen with declared or intended SEM majors attend large, lecture-based, fast-paced, hierarchically formatted classes (cf. Wineke & Certain, 1990). These classes are part of a system within the SEM disciplines that limits access to degrees by ''weeding out'' those whose academic abilities are allegedly not equal to the challenge (Massey, 1992; Seymour & Hewitt, 1997). These classes are frequently described as difficult, unmotivating, and unrelated to whatever initiated a student's intrinsic interest in science (Duderstadt, 1990; Treisman, 1992; Gainen, 1995). Even many well-prepared and bright students receive very low grades in these classes. Low grades in freshman classes usually mean the student has not developed the academic foundation required for success in subsequent classes. In addition, poor performance can have a negative effect on self-esteem, reduce a student's initial intrinsic interest in science (Seymour & Hewitt, 1997), and decrease the probability a second SEM course will be taken (Sabot & Wakeman-Linn, 1991).

African American Science Students

Two reasons are generally invoked to explain why so few African American college students persist and achieve within the SEM weed-out system. First, African American families have lower incomes than their White counterparts, making college tuition a difficult hurdle (e.g., Astin, 1982, 1990). Financial need frequently makes off-campus work a necessity, and this is negatively associated with college persistence in general (Callan, 1994), and success in SEM programs in particular (Garrison, 1987). However, a natural response to this challenge, financial support, has not appreciably increased the number of African American SEM baccalaureate recipients.

The second reason frequently invoked to explain the lower persistence rates of African Americans in SEM majors is their apparent competitive disadvantage in academic background. Black freshmen have lower SAT scores, lower high school grade point averages, and lower participation in advanced high school math and science courses than their Asian and White peers (Willingham, Lewis, Morgan & Ramist, 1990; Ramist, Lewis, & McCamley-Jenkins, 1994; Elliot, et al., 1995; Gandára & Maxwell-Jolly, in press). These factors have a strong and consistent positive relationship with freshman performance in quantitative (math and science) classes (e.g., Willingham et al., 1990; Elliot et al., 1995).

However, every year large numbers of African American students with high SAT scores, impressive high school GPAs, and success in high school honors math and science courses leave the science pipeline (cf. Seymour & Hewitt, 1997). In addition, many studies have reported that SAT scores are less predictive of performance for Black than for White students (e.g., Breland, 1979; Willingham et al., 1990; Ramist et al., 1994; Bowen & Bok, 1998). African American students with respectable SAT scores who underperform provide evidence that factors other than pre-collegiate preparation and native ability work to depress minority achievement and persistence. These factors may include academic and cultural isolation, motivational and performance vulnerability in the face of negative stereotypes and low expectations for performance, peers not supportive of academic success, and perceived and actual discrimination (cf. Garrison, 1987; Nettles, 1988; Allen, 1992; Steele & Aronson, 1995; Seymour & Hewitt, 1997; Gandára & Maxwell-Jolly, in press).

Enhancing SEM Achievement and Persistence for Highly Able African American Students

What can be done to facilitate strong SEM course performance, persistence in SEM majors and subsequent entrance to SEM graduate programs for highly able African American students? Consistent with extant research, influencing the following four sets of factors linked to student academic success appears especially important: academic and social integration, knowledge and skill development, support and motivation, and monitoring and advisement (cf. Hrabowski & Maton, 1995).

Academic and social integration appears critical to the success of African American SEM majors, including highly able ones. Black students have a higher probability of becoming academically and socially isolated on majority white campuses and in SEM majors than do White or Asian students (Nettles, 1988; Seymour & Hewitt, 1997). Research suggests that contact with faculty outside the classroom, and the development of mentoring relationships, including with minority faculty, can decrease academic isolation, and contribute to positive outcomes (Nettles, 1988; Hilton, Hsia, Solorano, & Benton, 1989; Redmond, 1990; Allen, 1992; McHenry, 1997; Seymour & Hewitt, 1997). Furthermore, increasing the number of like-minded, highly able Black student peers can substantially enhance peer academic and social support, reduce perceptions of racism, and increase cultural comfort in SEM classes—contributing to SEM academic persistence and success (Garrison, 1987; Nettles, 1988; Fries-Britt, 1994; Brazziel & Brazziel, 1997; Gandára & Maxwell-Jolly, in press).

Knowledge and skill development represent a second important focus for programmatic action. Involvement in peer study groups, for example, consistent with Uri Treisman's pioneering work, has been shown to result in enhanced technical knowledge mastery and course performance for SEM minority students (Treisman, 1992; Bonsangue & Drew, 1995; Kosciuk, 1997; Seymour & Hewitt, 1997; Gandára & Maxwell-Jolly, in press). Furthermore, strong study habits, time management skills, analytic problem-solving capacity, and the willingness to use available department and university resources have been linked to positive academic outcomes (Hilton et al., 1989; Atwater & Alick, 1990; Gandára & Maxwell-Jolly, in press).

Support and motivation represent a third set of factors linked to high levels of success in SEM majors. Appropriately, financial aid continues to be one of the cornerstones of African American student support (Gandára & Maxwell-Jolly, in press; Hilton et al., 1989), and in the case of SEM scholarships, can be made contingent on high levels of SEM course performance. However, due to the difficult nature of introductory and advanced science and mathematics courses, and the attractiveness of other majors, various other sources of support and motivational influence appear necessary as well to enhance SEM minority student persistence and performance (Seymour & Hewitt, 1997). These include high faculty expectations for African American student success, hands-on research experience, academically supportive friendship networks, involvement with faculty, tutoring, and emotional support during times of stress and difficulty (cf. Hilton et al., 1989; Seymour & Hewitt, 1997; Gandára & Maxwell-Jolly, in press).

Finally, monitoring and advising, if available on a regular, ongoing basis, can help students make wise academic decisions in selecting coursework, position themselves for graduate study, and prevent or limit the influence of emerging academic or personal problems. Consistent monitoring can help ensure regular assessment of a student's academic and social situation, and early warning signs of academic or personal problems (Gandára & Maxwell-Jolly, in press). Advising and feedback, including but extending beyond discussion of important academic requirements, can provide students with valuable input about their strengths, weaknesses, options, and potential consequences of various strategic plans of action (Glennan, Baxley &

Farren, 1985). Taken together, personalized monitoring and advising can help ensure that no student leaves or is unable to succeed in the SEM major because that student was not offered appropriate academic, psychological, and social resources and advice (Seymour & Hewitt, 1997).

Those universities committed to supporting African American and other underrepresented minority students in SEM majors strive to create environments which help to ensure student success. When this commitment is not made, we lose qualified African American SEM students to other majors, or from higher education totally. The Meyerhoff Scholars Program at University of Maryland, Baltimore County was developed in response to the low levels of performance and persistence of well-qualified SEM African American students on that campus. The program developers sought to incorporate multiple components addressing the broad range of factors linked in the literature to minority student success—that is, academic and social integration, knowledge and skill development, support and motivation, and advising and monitoring. The immediate goal of the program was to effect substantial increases in qualified Black students' SEM course performance, completion of major, and entrance into SEM graduate programs; the longer term goal was to increase the number of African American scientists.

The Meyerhoff Scholars Program

The Meyerhoff Scholars Program began as a collaboration between philanthropists Robert and Jane Meyerhoff and the University of Maryland, Baltimore County in 1988. The Meyerhoffs provided $500,000 for a program to address the lack of African Americans, especially male African Americans, in the science, math, and engineering pipeline. Letters soliciting nominations were sent to principals and guidance counselors throughout Maryland requesting their "best and brightest." Forty nominations were received that year and 19 male African American students became the first Meyerhoff Program students. (Among those accepted, Meyerhoff Scholars receive a free tuition, room and board scholarship while Meyerhoff Finalists receive somewhat smaller, partial scholarships. Both Scholars and Finalists are included in all analyses in the current study.) The following year, the program admitted women. Currently, between 40 and 60 Meyerhoff students are selected each year from over 1,400 nominations and applications from across the nation.

The academic criteria necessary for acceptance into the Meyerhoff Scholars Program have been increasing steadily over the years. The 1998 entering cohort of African American Meyerhoffs had mean SAT-Math scores of 657, mean SAT-Verbal scores of 623, and a mean high school GPA of 3.77. Prospective Meyerhoff students cannot have received lower than a B in any high school science or math course, and many have completed a year or more of calculus in high school. Preference is given to those who have taken advanced placement courses in math and science, have research experience, and provide strong references from science or math instructors. Additional criteria include a commitment to stay in the sciences and a desire to "give back" to the communities from which they came. The program's web site is: http:\www.umb.edu.

In 1996, the Meyerhoff Scholars Program was recognized nationally with the Presidential Award for Excellence in Science, Math, and Engineering Mentoring. The program incorporates 14 different components, briefly described below.

Financial Aid. The Meyerhoff Program provides students with a comprehensive financial package including tuition, books, and room and board. This support is contingent upon maintaining a B average in an SEM major.

Recruitment. The program currently receives approximately 1,400 nominations and applications each year. The top 100–150 applicants and their families attend one of the two recruitment weekends on the campus. This weekend provides an opportunity for faculty, university administrators, program staff, and current students to meet the applicants under both formal and informal circumstances, and to give incoming students a chance to interact with potential peers, faculty, and staff.

Summer Bridge Program. Once selected for the program, Meyerhoff students attend a mandatory pre-freshman Summer Bridge Program, and take courses in math, science, and African American studies. They also attend social and cultural events. The purposes of the Summer Bridge Program are to prepare students for the new expectations and requirements of college courses, and to provide social opportunities for interacting with peers, faculty, and staff.

Study Groups. Group study is strongly encouraged by the program staff, as it is viewed as an important part of succeeding in SEM majors. Study groups promote academic support and create opportunities for social support and interaction.

Program Values. Program values include support for academic achievement, seeking help from a variety of sources, peer supportiveness, high academic goals (with emphasis on Ph.D. attainment and research careers), and giving back to the community. Beginning at the recruitment phase, the shortage of African American science Ph.D.s is discussed, and the importance of achieving a research-based Ph.D. is emphasized. An M.D. degree is considered a disappointment given the program's focus on producing Ph.D. level researchers, and students know this.

Program Community. The Meyerhoff program provides a family-like social and academic support system for students. Students live in the same residence hall during their first year, and are required to live on campus during subsequent years. In addition to peer connectedness, students are in continual contact with program staff, who are highly accessible and involved in student life. Program students and staff meet in large "family" meetings on a regular basis.

Personal Advising and Counseling. The program employs full-time academic advisors and other staff members who monitor and advise students on a regular basis. When students do poorly in a key science course, program staff strongly encourage students to retake the course. Counselors are not only concerned with academic planning and performance, but also with any personal problems students may have.

Tutoring. The program staff strongly encourages Meyerhoff students to either tutor others or be tutored to maximize academic achievement. Tutors are regularly identified from within and outside the program.

Summer Research Internships. Each student participates in summer research internships. These internships allow the hands-on opportunities that maintain intrinsic interest in SEM careers and also create opportunities for mentoring relationships.

Faculty Involvement. Key SEM faculty and department chairs are involved in the recruitment and selection phases of the program. As time permits, these faculty and department chairs also participate in social activities, presentations, and informal and formal discussions with Meyerhoff candidates and students. Many faculty provide opportunities for student lab experience to complement summer research assistantships.

Administrative Involvement and Public Support. The Meyerhoff Program is supported at all levels of the university, including ardent support from the President. Over the years the program has generated a substantial amount of public recognition and support.

Mentors. Each student is paired with a mentor who is a professional in an SEM occupation. Mentoring environments can create excitement about and active involvement with science.

Community Service. All students are encouraged to take part in a community service activity, which often involves volunteer work with at-risk Baltimore youth. This component helps concretize the program value of "giving back" to the larger community.

Family Involvement. Parents are included in social events, and kept advised of their child's progress. The parents have formed the Meyerhoff Family Association which serves as a mutual support program.

Initial Findings and Current Study

Initial findings, focused on freshman year outcomes, are promising. Hrabowski & Maton (1995) compared students in the first three UMBC Meyerhoff Program cohorts to a UMBC historical (pre-Meyerhoff) sample of African American students who met the entrance requirements of the program (and a subsample matched on gender, high school GPA and SAT scores). The Meyerhoff students had significantly higher overall GPAs and SEM GPAs freshman year than did the historical comparison students. In addition, their grades in critical "gateway" freshman-year courses—calculus, physics, and chemistry—were significantly higher than those of the historical samples.

Despite the promising nature of this initial report, it had several limitations. First, time-linked historical effects—such as changes in the university and societal environments—may have accounted for the better Meyerhoff student performance relative to the historical African American student sample. Second, the comparison group did not go through the same selection process as the Meyerhoff students did. Third, key longer term goals of the Meyerhoff Program, including graduation in SEM majors and acceptance to SEM graduate school, were not assessed.

The current study builds upon and extends our previous research. The overarching research question is whether the Meyerhoff Program has a positive, longer term impact, and if so, which factors appear to contribute to program effectiveness. Academic outcomes after 5 years are assessed for the first three coeducational cohorts of Meyerhoff students. Specifically, we examined bachelor-level retention and graduation rates in SEM major, SEM GPA, overall GPA, and SEM graduate and professional school admission rates for the Meyerhoff and comparison students. Meyerhoff student performance was compared to that of two different African American student samples: (1) SEM students who had been offered Meyerhoff scholarships, but chose instead to attend other institutions, and (2) a historical cohort of academically comparable SEM students at UMBC. We also included both historical and current Caucasian and Asian samples to investigate their performance in relation to their African American peers. It is believed that the multiple comparison samples, taken together, allow us to test the Meyerhoff program's efficacy in a relatively comprehensive way.

In addition, surveys and interviews with Meyerhoff students, and interviews with science faculty provided data for a process evaluation analysis. Using these data, we were able to discern which program components the Meyerhoff students perceived as especially important and why. Faculty perceptions of program impact on their departments and on the larger university were also examined.

Method

Research Participants

Primary Meyerhoff Sample. The 93 Meyerhoff students from the first three coeducational entering classes constituted the primary Meyerhoff sample in the current research. Of these participants, 15 began in 1990, 35 began in 1991, and 43 began in 1992. During the early years of the program, the minimum requirements for selection were an SAT-M score above 550, a combined SAT score of at least 1050 (not re-centered), and a high school GPA above 3.0. (In several cases, students with a high school GPA above 3.7, an SAT-M score better than 500, and a combined SAT score better than 1000 were accepted.) The Meyerhoff sample in the current study had a mean SAT-Math score of 633.9, a mean SAT-Verbal score of 548.9, and a mean high school GPA of 3.48. All students had declared majors in SEM (science, engineering, or math).

Non-UMBC ("Declined") African American Comparison Sample. One primary comparison sample (the "declined" sample) consisted of 35 African American students who were offered Meyerhoff scholarships between 1990 and 1992, but declined and attended other institutions. This sample included only students who took at least three SEM courses during their freshman year. Table 1 (top portion) describes the characteristics of the Meyerhoff and Declined samples.

Preliminary analyses indicated that there were more males in the Meyerhoff (53.8%) than in the Declined (34.3%) sample, χ^2 (1) = 3.86, $p < .05$. In addition, Meyerhoff students had lower SAT-Verbal (mean = 548.9) scores than the Declined students (mean = 581.1), t (126) = −2.89, $p < .01$. There were no differences on SAT-Math, high school GPA, number of freshman year SEM courses, year of entry, or full versus partial Meyerhoff scholarship offer. Given the potential importance of the differences in gender representation across samples, secondary analyses were performed on the three criteria variables for men and women separately.

UMBC-Based Comparison Samples

Full Sample. The full historical comparison samples consisted of 39 African American, 138 Asian, and 863 Caucasian students who attended UMBC before the Meyerhoff Program began in 1989, met the same admissions criteria as the Meyerhoff students, took a minimum of three SEM courses, and completed at least 10 SEM credits in their freshman year. The full current samples consisted of 88 Asian and 270 Caucasian students who entered UMBC between 1990 and 1992, met the same admissions criteria as the Meyerhoff students, took in their freshman year a minimum of three SEM courses, and completed at least 10 SEM credits. All current African American students meeting these criteria were Meyerhoff students.

The six groups differed significantly on a number of background and academic variables, including gender, SAT-Math, SAT-Verbal, and number of freshman year science courses. The

Table 1

Demographic, pre-college academic, and college descriptive variables for Meyerhoff and comparison samples

	Male (%)	SAT-Math	SAT-Verbal	High School GPA	Number freshman SEM Courses	Year of Entry	Full Scholarship Offer
Meyerhoff and (non-UMBC) Declined Comparison Sample							
Meyerhoff Students ($N = 93$)	53.8*	633.9 (52.0)	548.9** (54.6)	3.48 (0.33)	5.3 (1.1)	1991.3 (0.7)	52.7%
Students who Declined Offer ($N = 35$[a])	34.3	626.9 (48.9)	581.1 (56.9)	3.55 (0.37)	4.8 (1.5)	1991.3 (0.7)	54.2%
Meyerhoff and UMBC-Based Comparison Samples: Matched Subsample							
UMBC Historical Samples							
African American ($N = 31$)	29.0	611.6 (46.3)	528.7 (72.1)	3.43 (0.34)	5.5 (1.9)	1984.5 (3.9)	n/a
Asian ($N = 31$)	29.0	621.3 (40.6)	519.0 (73.4)	3.51 (0.28)	5.2 (1.3)	1985.2 (3.0)	n/a
Caucasian ($N = 31$)	29.0	615.5 (41.1)	537.1 (51.6)	3.47 (0.28)	5.2 (1.5)	1984.8 (3.2)	n/a
UMBC Current Samples							
Meyerhoff Students ($N = 31$)	29.0	611.6 (38.0)	543.2 (44.4)	3.49 (0.29)	5.4 (0.8)	1991.2 (0.6)	29.0%
Asian ($N = 31$)	29.0	618.7 (45.0)	523.9 (70.6)	3.42 (0.32)	5.6 (1.1)	1991.2 (0.9)	n/a
Caucasian ($N = 31$)	29.0	616.8 (40.6)	545.5 (71.8)	3.52 (0.28)	5.5 (1.2)	1991.2 (0.7)	n/a

[a] For Number Freshmen Year Science Courses, $N = 24$.
$**p < .01$.
$*p < .05$.

historical African American group contained the fewest males (33.3%), the lowest SAT-Math scores (604.4), the historical Asian group the lowest SAT-Verbal scores (495.3), and the current White students the fewest freshman science courses (5.1). Due to these differences, the primary analyses of the UMBC-based comparisons focused on a matched subsample.

Matched Subsamples. Thirty-one matches, each containing six students, were generated resulting in a total matched subsample of 186 students across the six groups. The matching variables were Gender, SAT-Math, SAT-Verbal, high school GPA, number of freshman science courses, and (within time period) year of entry (see Table 1, bottom portion, for subsample means). All primary analyses were conducted on the matched samples, although parallel analyses were also conducted on the full sample, and findings reported when they differed.

Procedure

Non-UMBC-Based ("Declined") Sample. University transcripts were acquired for all of those students who had provided informed consent (usually at the point of applying to the Meyerhoff Program). Telephone calls to university registrars' offices provided information about major and graduation status for 11 students for whom informed consent was not obtained. Post-graduate information was obtained directly from students, family members, departmental records, or university officials. All post-graduate education information was confirmed (or in some cases clarified) by phone calls to graduate and professional school registrar offices.

UMBC-Based Samples. A computerized database was provided by the university for all UMBC students in the sample, and copies of all student transcripts as of Fall, 1997 were obtained as well. Information on post-graduate institutions selected by the historical and Meyerhoff African American samples was obtained in the same manner used with the declined sample—from students, family members, departmental records, or university officials. It was confirmed (or clarified) by phone calls to graduate and professional school registrar offices. In order to find out about post-graduate education for non-African American students, a mailed survey of all students in the sample was conducted in 1996 in conjunction with the UMBC alumni office, and followed up with two phone calls to non-respondents for whom phone information was available. Usable information was obtained from 450 alumni, representing 37% of the total sample.

Primary Researchers. The primary researchers are a Caucasian Professor of Psychology at UMBC, and the current UMBC President, an African American mathematician and founder of the Meyerhoff Program.

Measures

Demographic and Academic Background Variables. Ethnicity, gender, university entrance date, SAT scores (both math and verbal), and high school GPA were obtained from university application records. For students who applied to the Meyerhoff Program, scholarship status (full vs. partial scholarship offered) was also obtained.

Freshman Year SEM Major and Coursework. Freshman year records were reviewed to determine the number of SEM courses and credits attempted and completed, and whether the student had a declared SEM major. SEM courses and majors included were: biology, chemistry, computer science, engineering, mathematics, and physics.

Graduation Major, Last Major, or Current Major. Graduation major, last major (for those no longer in school who had not graduated), or current major (for those still in school) were obtained from university records. The outcome variable SEM major contained four categories: (1) SEM graduate; (2) likely to be SEM graduate (for those still attending school and pursuing an SEM major); (3) non-SEM graduate (for those who graduated in a non-SEM major; and (4) not likely to graduate in SEM (for those who had not graduated and were no longer enrolled, or who were still in school but pursuing a non-SEM major).

SEM and Overall GPA. SEM GPAs were hand-calculated from transcripts obtained in Fall, 1997. Only courses in the six SEM disciplines noted above were included. SEM GPA is an important indicator of achievement in SEM per se, and an indicator of competitiveness for admission to SEM graduate school or a professional school. Overall GPA was the composite for all coursework taken. Consistent with UMBC practice, the highest grade received for a repeated course was used in all GPA calculations.

Graduate Education. The SEM graduate education outcome variable contained four categories: (1) in graduate school in a SEM program (includes M.D./Ph.D. programs); (2) in medical school or other SEM professional school; (3) still enrolled in SEM undergraduate major; and (4) no post-college education in SEM. This latter category includes students who did not graduate, those who graduated in a non-SEM major (unless follow-up indicated they attended medical school), SEM graduates who did not pursue graduate or professional education, and those who attended non-SEM graduate (e.g., Psychology) programs.

Process Evaluation

Process evaluation data were collected at various points of time, in various formats, from multiple subgroups of Meyerhoff students (e.g., freshmen; graduating seniors; all cohorts on campus) about their experience in the university and in the Meyerhoff Program. The process evaluation sample includes, but is not limited to, students in the 1990–1992 entering classes (i.e., 5-year outcomes study sample). The primary purposes of the process evaluation were: (1) to help establish which program factors were perceived as most important, through pre-designated survey items and through spontaneously generated responses to open-ended interview questions; (2) to identify negative aspects of the program (interviews); and (3) to suggest from the student perspective why various components of the program may be important (interviews).

In addition, a small sample of science faculty were interviewed, to assess their perceptions of program impact on their departments and on the university more generally. The primary purpose of these exploratory interviews was to suggest any areas of program impact beyond Meyerhoff student outcomes per se.

Content analysis was used to identify prominent themes in the student and faculty interview data. The qualitative results were intended to supplement, support, and enrich the quantitative survey data.

Quantitative Data. Anonymous quantitative process data were collected from different samples of students in the Meyerhoff Program: 1991 entering class in Spring, 1992 ($N = 30$), all students in Spring, 1994 ($N = 117$), graduating seniors in Spring, 1996 ($N = 22$), and all students in Spring, 1998 ($N = 140$). In each case, 80% or more of the targeted Meyerhoff students completed questionnaires. Each survey listed 17 factors encompassing the various identified program components. Students rated the extent to which each factor contributed to their academic success on 5-point, likert-type rating scales (i.e., 1 = not at all, 5 = large extent). To establish an overall rating, the means across the four administrations were averaged (i.e., independent of sample size a given year).

Qualitative Data. Semi-structured interviews focused on the Meyerhoff student experience were conducted on several occasions. In each case, the interviews were tape-recorded, and research confidentiality was assured. In the Spring of 1995, 24 Meyerhoff students from each of the then-current Meyerhoff cohorts were randomly selected. Two of the interview questions were open-ended and allowed students to describe spontaneously how the program aided them.

Specifically, students were asked (1) "What has your experience as a Meyerhoff student been like at UMBC" and (2) "Do you feel your experiences at UMBC would be different without the Meyerhoff Program?" The interviewer, a female African American graduate student, probed for references to specific examples.

In addition, a different female African American graduate student interviewed six graduating Meyerhoff seniors in the Spring of 1993 and three graduating seniors in the Spring of 1994 about their experiences in the Meyerhoff program. The questions chosen for analysis were: (1) "What are the positive aspects of being in the Meyerhoff Program? The negative aspects?" and (2) "Have your experiences as a Meyerhoff student been similar to those of other African American students? Different from those of other African American students?" Again, the interviewer probed for references to specific examples.

Each response to these questions was coded to indicate references to specific program components, and whether each reference was positive or negative. The percentage of students indicating a specific component as a strength or weakness was tabulated, and illustrative quotes selected.

Ten faculty from the Biology ($N = 4$) and Chemistry ($N = 6$) Departments who in the past few years have had one or more Meyerhoff students work in their research labs were interviewed by the first author in Fall, 1999. Faculty were asked in open-ended fashion their perceptions of the impact of the Meyerhoff Program on their departments, and on the university more generally. Interviews were tape-recorded, and confidentiality of responses was ensured. Questions focused on perceptions of both positive and negative areas of program impact. Content analysis was performed to assess primary interview themes.

Results

Declined Sample

Graduation Major. As expected, the Meyerhoff students demonstrated greater success in the SEM area than equally talented students who declined the Meyerhoff offer and attended other universities. As shown in Table 2 (top portion), the Meyerhoff students were nearly twice as likely as the Declined sample to retain and graduate in SEM majors, χ^2 (3) $= 27.8$, $p < .01$. The exact same pattern of findings appeared when analyses were conducted separately for male, χ^2 (3) $= 14.8$, $p < .01$, and female, χ^2 (3) $= 13.7$, $p < .01$, students.

GPA. Furthermore, a MANCOVA analysis indicated that the Meyerhoff students achieved significantly higher SEM GPAs than the Declined sample, F (1,110) $= 7.16$, $p < .01$ (Table 2, middle). Covariates included gender, SAT math and verbal scores, high school GPA, and scholarship status. Interestingly, there were no significant differences between the two groups in terms of overall GPA, F (1,110) $= 1.31$, ns. These findings suggest that the impact of the program is specific to success in SEM disciplines (i.e., the Declined students who switched to non-science majors did quite well in those majors).

Graduate and Professional School. Consistent with the higher rates of graduation in SEM majors and higher SEM GPAs, the Meyerhoff students were more likely to attend SEM graduate school, χ^2 (3) $= 18.3$, $p < .01$. As Table 2 (bottom portion) shows, almost half of the Meyerhoffs went on to SEM graduate school, whereas fewer than one in ten of the Declined sample did so. Interestingly, relatively equal numbers of Meyerhoff and Declined sample students were in medical school (non-M.D./Ph.D. programs). Overall, approximately 70% of Meyerhoff students

Table 2

Academic outcomes: Meyerhoff students and students who declined Meyerhoff scholarship offer (and attended another university)

	Not Likely to Graduate in SEM[a]	Graduated in Non-SEM Discipline	Likely to Graduate in SEM	Graduated in SEM Discipline	Total N
SEM Graduation Major					
Meyerhoff students	7 (7.5%)	5 (5.4%)	4 (4.3%)	77** (82.8%)	93
Students who Declined Meyerhoff Offer	3 (8.6%)	15 (42.9%)	1 (2.9%)	16 (45.7%)	35
	Actual SEM GPA	Adjusted[b] SEM GPA	Actual Overall GPA	Adjusted Overall GPA	
SEM GPA and Overall GPA					
Meyerhoff students ($N = 93$)	3.16	3.16** (0.43)	3.32	3.33 (0.35)	
Students who Declined Meyerhoff Offer ($N = 24$)	2.90	2.89 (0.60)	3.26	3.24 (0.44)	
	No Post-College SEM	SEM Major Still in College[c]	Medical School	SEM Graduate Program	Total N (Not Known)
SEM Graduate Education					
Meyerhoff students	23 (24.7%)	5 (5.4%)	22 (23.7%)	43** (46.2%)	93 (0)
Students who Declined Meyerhoff Offer	20 (58.8%)	2 (5.9%)	9 (26.5%)	3 (8.8%)	34 (1)

[a]SEM (Science, Engineering, Mathematics) disciplines included: Biology, Chemistry, Computer Science, Engineering, Mathematics, Physics.
[b]Means were adjusted for: Gender, SAT Math, SAT Verbal, High School GPA, and Scholarship Status.
[c]One student graduated in a SEM major, but has returned to college to pursue a second SEM major.
**$p < .01$.

and 35% of Declined sample comparison students had entered SEM graduate or professional schools 5 years after entering college.

The same pattern of findings appeared when analyses were conducted separately for the male students, χ^2 (3) = 15.1, $p < .01$. For the female students, the results were not significant using the Pearson test, χ^2 (3) = 5.3, $p < .15$, although significance was achieved using the Mantel–Haenszel test of linear association, χ^2 (1) = 4.6, $p < .05$ (among Meyerhoff females, 25.6% were not in and were not likely to enter SEM graduate or programs, 4.7% were still in undergraduate science majors, 32.6% were in SEM professional schools, and 37.2% were in SEM graduate programs; the corresponding percentages for Declined sample females were 47.8, 4.3, 34.8, and 13.0%, respectively).

UMBC Comparison Samples

A similar pattern of findings emerged with the UMBC-based historical African American comparison sample as with the declined sample. In order to help rule out cohort effects due to the different time periods involved, the graduation major and GPA analyses keyed on comparing this historical black SEM sample with their historical Asian and White counterparts, and then examining whether the pattern was altered when the Black Meyerhoff students were compared with their contemporaries.

Graduation Major. In terms of graduation major, there was a significant difference across the six matched samples, χ^2 (15) $= 48.1$, $p < .01$. As Table 3 shows, all three historical samples had relatively equal rates of graduation in an SEM major. However, in a striking alteration of pattern, the Meyerhoff students were substantially more likely to retain and graduate in SEM majors than their contemporary Asian and White peers. The exact same pattern emerged for the full (non-matched) sample, χ^2 (15) $= 145.43$, $p < .01$, and also when separate full-sample analyses were conducted for males, χ^2 (15) $= 105.79$, $p < .01$, and females, χ^2 (15) $= 55.79$, $p < .05$.

GPA. The time period by ethnic group MANCOVA analyses revealed a statistically significant interaction for SEM GPA, F (2, 176) $= 6.78$, $p < .01$ (Table 4). Covariates included

Table 3
Graduation majors: UMBC historical (pre-Meyerhoff) and current comparison samples and Meyerhoff students: Matched Subsample[a]

	Not likely to graduate in SEM[b,c]	Graduated in non-SEM discipline	Likely to graduate in SEM[d]	Graduated in SEM discipline
Historical samples				
African American ($N = 31$)	8 (25.8%)	6 (19.4%)	0 (0.0%)	17 (54.8%)
Asian ($N = 31$)	8 (25.8%)	10 (32.3%)	0 (0.0%)	13 (41.9%)
Caucasian ($N = 31$)	13 (41.9%)	4 (12.9%)	0 (0.0%)	14 (45.2%)
Current samples				
Meyerhoff ($N = 31$)	2 (6.5%)	1 (3.2%)	0 (0.0%)	28** (90.3%)
Asian ($N = 31$)	10 (32.3%)	4 (12.9%)	4 (12.9%)	13 (41.9%)
Caucasian ($N = 31$)	14 (45.2%)	7 (22.6%)	1 (3.2%)	9 (29.0%)

[a]Students were matched on Gender, SAT-Math, SAT-Verbal, High School GPA, and Number Freshman Year SEM Courses Taken.
[b]SEM (Science, Engineering, Mathematics) disciplines included: Biology, Chemistry, Computer Science, Engineering, Mathematics, Physics.
[c]This category includes students who stopped before completing a degree and those who are still in school but are not pursuing a SEM major.
[d]This category includes students who are still in school pursuing a SEM major.
$^{**}p < .01$.

Table 4
SEM GPA[a] After 5 years of college: UMBC historical (pre-Meyerhoff) and current comparison samples and Meyerhoff students: Matched subsample

SEM[a] and overall GPA after 5 years of college				
	Actual SEM GPA	Adjusted[b] SEM GPA	Actual Overall GPA	Adjusted Overall GPA
Historical samples				
African American ($N = 31$)	2.59	2.64 (0.73)	2.80	2.84 (0.71)
Asian ($N = 31$)	3.00	2.96 (0.63)	3.23	3.22 (0.55)
Caucasian ($N = 31$)	2.94	2.94 (0.65)	3.14	3.13 (0.58)
Current samples				
Meyerhoff ($N = 31$)	3.17	3.16** (0.39)	3.33	3.30** (0.30)
Asian ($N = 31$)	2.87	2.92 (0.56)	3.13	3.17 (0.46)
Caucasian ($N = 31$)	2.84	2.79 (0.65)	3.12	3.07 (0.56)

[a]All biology, chemistry, computer science, engineering, mathematics and physics courses taken during the first 5 years of college were included in calculating the SEM (Science, Engineering, Math) GPA.
[b]Means were adjusted for Gender, SAT-Math, SAT-Verbal, and High School GPA.
** $p < .01$ (MANCOVA Ethnicity × Time Period interaction).

gender, SAT math and verbal scores, and high school GPA. Whereas the African American historical sample achieved significantly lower SEM GPAs than their Asian, $t = 2.31$, $p < .05$, and Caucasian, $t = 2.14$, $p < .05$, counterparts, the Meyerhoff students achieved SEM GPAs comparable to their Asian peers, $t = 1.76$, ns, and somewhat higher than their Caucasian peers, $t = 2.69$, $p < .01$.

Table 4 reveals a similar interaction pattern for overall GPA, F (2, 176) = 5.82, $p < .01$. Although the African American historical sample achieved significantly lower overall GPAs than their Asian, $t = 3.02$, $p < .01$, and Caucasian counterparts, $t = 2.37$, $p < .05$, counterparts, the Meyerhoff students achieved similar overall GPAs to their Asian peers, $t = 1.05$, ns, and somewhat higher overall GPAs than their Caucasian peers, $t = 1.90$, $p < .06$.

The same general pattern emerged for the full sample for the SEM GPA interaction F (2, 1481) = 9.83, $p < .01$, and for the overall GPA interaction F (2, 1481) = 9.34, $p < .01$. The historical sample of African American students earned significantly lower SEM GPAs and overall GPAs compared to their Asian and Caucasian counterparts. In contrast, the Meyerhoff students earned SEM GPAs and overall GPAs similar to or slightly higher than the current samples of Asian and Caucasian students.

Graduate and Professional School. Postcollege outcome analysis focused primarily on the two African American samples, because high quality data were not available for the Asian and Caucasian samples. Consistent with the higher rates of graduation in SEM majors and higher SEM GPAs, Table 5 shows that the Meyerhoff students were more than 10 times as likely than

Table 5
Graduate education outcomes for Meyerhoff students and historical African American comparison sample students: Matched subsample

	No post-college SEM[a]	SEM major still in college	Medical school	SEM graduate program	Total N known (Not Known)[b]
Graduate Education					
Historical African American students	22 (78.6%)	0 (0.0%)	5 (17.9%)	1 (3.6%)	28 (3)
Meyerhoff students	8 (28.6%)	0 (0.0%)	8 (28.6%)	12** (42.9%)	28

[a]This category includes students who stopped before completing a degree, those who graduated in a non-SEM (non-Science, Engineering, or Mathematics) major unless follow-up indicated they attended medical school, and those who graduated in a SEM major but did not pursue post-undergraduate degree education. Post-college SEM areas include Ph.D, M.S., and M.D./Ph.D. programs in biology, chemistry, computer science, engineering, mathematics, and physics.
[b]"Total N Known" refers to all graduates for whom information about post-college education was available, plus all non-graduates. The "Unknown" subtotal (in parentheses) refers to all graduates in a SEM major for whom information about post-college education has not yet been obtained. The three Meyerhoff students matched to the three comparison students for whom information was not known were excluded from the analysis.
$^{**}p < .01$.

the historical African American sample to attend graduate school in SEM fields, χ^2 (2) $= 16.5$, $p < .01$, and almost two times as likely to attend medical school. Comparable findings were obtained for the full sample, χ^2 (3) $= 50.0$, $p < .01$.

Unfortunately, the only source of comparable data for the Asian and Caucasian samples is based on survey data with a low return rate. Although these data should be treated with caution, it is noteworthy that the increase from the historical African American sample to the Meyerhoff sample in percent attending SEM graduate schools did not occur for the other groups. Specifically, 23.1% of the historical Asian sample returning surveys (total $N = 26$) and 24.3% of the Caucasian historical samples returning surveys (total $N = 300$) attended SEM graduate programs, whereas only 11.1% of current Asians (total $N = 18$) and 17.9% of current Caucasians (total $N = 106$) reported attending SEM graduate school. These findings are paralleled in the matched subsample, but sample sizes were extremely small (a range from 3 to 7 completed surveys for the four matched subsamples).

Process Evaluation Results

The survey and interview process evaluation data revealed that a number of program factors were viewed as especially critical by students: Program Community, Study Groups, Summer Bridge Program, Financial Support, Program Staff, Research Internships and Mentors, and Campus Academic Environment. Each of these is briefly discussed below.

Program Community. "Being part of the Meyerhoff Program Community" was consistently rated on surveys as a primary contributor to academic success (mean across four administrations = 4.2, on a 5-point scale). Two specific facets of student involvement in the program, Study Groups and Summer Bridge Program, received similarly high ratings (means of 4.3 in each case). The survey results were strongly supported by the interview findings, in which students spontaneously generated the program component(s) perceived as important to their success. Approximately 85% of the students interviewed cited facets of program community as the most positive aspect of the program.

A number of students emphasized the importance of the peer academic facet of the program community, as reflected in the illustrative quotes from two students below.

> Number one in my book is the support. Having other smart, talented African Americans around you at all times is an asset. In high school I didn't have that. I could count on one hand the number of smart, intelligent Black people that I could come to and say, "I'm having problems in this class . . . Maybe you can help me out, direct me to someone I can speak to."

> Without the Program, initially it would be much more difficult, at least academically. I would be much more alone going to classes. You know that there is a sort of net under you in case you fall.

Other students described the family-like nature of the program community, and the importance of friendship networks, as illustrated in the next three quotes.

"The Meyerhoff Program is like a family, and that adds a lot of support. There is a lot of help. You don't have to assume all the responsibility yourself at once."

"We always have what they call "family meetings" where we all get together. Students who have done well are praised. They can raise their hands and say what grades they have gotten in their courses. So there is a chance for all students to be recognized in front of the group for doing well."

"It would have taken me a while to become social with people. But in my first year of college, I knew about thirty people [Meyerhoff peers], so it was easy. I had friends. I didn't feel like an outcast."

The final two quotes focus on responsibility and pride associated with membership in the program community.

"I feel that it is my obligation to give something back, whether it be some test notes or class notes or solutions, things like that, to help out my little [Meyerhoff] brothers and sisters."

"When you go out in public, you're not only representing yourself, but you are representing the program. So you carry yourself with a little more pride, and a little more dignity."

Taken together, the interview excerpts illustrate how a critical mass of talented minority students can positively affect student academic achievement. In related fashion, they provide evidence that having a critical mass of such students on a campus enhances minority students' academic and social integration into the university environment.

Financial Support. Financial support was the most highly rated item over the years (mean $=4.4$). Furthermore, nearly one fourth of the students interviewed specifically cited financial support as an important factor in their Meyerhoff success. The financial aid was described as liberating, for the students and their families. It was also perceived as a strong incentive to pay back the community and to avoid failure. Two representative quotes are included below.

"The financial support is a whole other aspect, because you don't have to worry about a whole lot of things . . . having to get a job if you couldn't afford college, or putting that burden on your parents . . . So, that's [a lot of stress] off your mind."

"You don't have to worry about money, like a lot of other students who have to take a job to get through school. The Meyerhoff Program, you just do your work and everything is taken care of for you, so you can concentrate completely on academics."

Program Staff. Program staff were consistently identified by students as central to their academic success (mean rating $=4.2$). Furthermore, support from the Meyerhoff staff was spontaneously mentioned by approximately two-thirds of the students interviewed. Students characterized the program staff as encouraging and supportive, concerning both their personal and academic lives. Staff monitoring of student academic progress was perceived as motivational. Staff knowledge of university resources guided students through and lessened the impact of personal, academic, and financial problems. Three representative quotes are included below.

“Meyerhoff Program staff will tell you if you’re not doing well… They are really helpful in the sense that if you have a problem, they will listen to it. They’ll push you to get good grades, and if you get good grades, you will be rewarded.”

“[The Meyerhoff staff] are definitely committed to us. They want to make sure we’re staying involved with our academics…staying in touch with other students in the program. They want to make sure that we’re networking and that we’re basically getting the most that we can get out of being here. They’re constantly calling us or saying here’s this activity or here’s an internship I think you would be great for. That type of thing.”

“The Meyerhoff staff really push you. You know they believe in you, and that helps you even more.”

Research Internships and Mentors. Summer research internships were another program component rated by students as important contributors to their success (mean $=4.2$). These internship opportunities, and academic mentors more generally, were mentioned enthusiastically by approximately one-fifth of the students interviewed. The internships provide hands-on, meaningful research that gives students a realistic look at what scientists do. For many Meyerhoff students, these experiences have helped them confirm their desire to pursue the Ph.D. In fact, many of these students have either published in refereed journals with mentors or presented papers at professional conferences. Descriptions of research experiences from two students are excerpted below.

“The research experiences have been very valuable. I worked with Dr. Jones my first year, and he set a basis for everything that I was going to be using later on. Then Dr. Farkson—I presented at three difference conferences on the research that I did with him about myoglobin. Then I worked with Dr. Howard. He works in neuroscience, and his work was pretty interesting too…[Most valuable has been] the thinking process, how you go about trying to solve a problem, and all the different techniques you can use to get around problems. That, and all the contacts.”

“Every summer I worked, I did research. My first year, I worked with Dr. Neeman. He is an African American, and one of the mentors for our program. We did basic stuff to help me along. When I did my research next year, [I found] it really did [help]. The next year, I worked with Dr. Stevenson; he took an interest in me. He really kind of molded me along, and he guided me a lot. He actually helped me to apply to Harvard. Then Dr. Brimmer, this year—he’s a real big name at Hopkins, so it was good working with him and with his graduate students.”

Some student responses suggested the special importance of a mentor who was African American, or in the case of female students, who was of the same gender.

“I was lucky enough last year to get an internship in a Black professor’s lab. I feel like I got to know him pretty well. We just talked sometimes, you know, just about the future and stuff like that, ways that I could do things in the future, different directions I could take.”

“[My mentor and I] talk about research, and about being a minority in science and being a woman, things like that. We’ve developed a good relationship, and [I’ve received] a lot of emotional support.”

Campus Academic Environment. Although not a component of the program per se, and not assessed directly in the surveys, more than one-third of the students interviewed spontaneously identified facets of the campus academic environment as important contributing factors to their success. Specifically, students emphasized that as Meyerhoffs they benefitted from high expectations from faculty and enhanced access to faculty, as revealed in the three quotes below.

“After faculty figure out that you’re a Meyerhoff, I guess there’s this underlying assumption that you’re going to do well . . . there’s a little more motivation in that class [when] he knows that I’m a Meyerhoff.”

“An advantage [of being a Meyerhoff student] is that we get to meet [faculty members] and they get to know us personally. So, if we have any problems we feel comfortable going up and talking to them and asking them questions.”

“It seems like everybody thinks that if you are a Meyerhoff, then you must be smart. I get that from teachers and people who just work here. It’s nice attention. They seem to admire you a lot and they seem to have a genuine sense of caring for your education.”

Negative Aspects of the Program Experience. Both the survey and the interview results underscore the positive contribution of the Meyerhoff Program to student academic success. However, after noting positive facets of the program in the interviews, some students noted a few negatives as well. The first three students below focus on the difficulties involved in coping with high expectations, careful scrutiny, and high program status.

“Because the program is so popular . . . the faculty members recognize us more . . . when we get in their classes they may know us before we know them, and they may expect more from us because they know we’re Meyerhoff students, so that can be a disadvantage.”

“I do kind of feel like I’m always being watched and sometimes I would like [not] having everyone looking to see how I do. There’s just . . . no freedom.”

“Sometimes teachers will expect more from you than other people, plus, everyone [in the program] will know your grades, test grades and so forth. That’s okay, that’s part of the support system, but at times it can be real trying.”

The final student quoted below discusses alienation from other students on campus.

“The down side of it sometimes is that you feel alienated when you come to the campus, because you spent the summer together. You have already had a label placed on you and it reduces your chance of meeting people on an equal basis . . . that goes for White people and Black people.”

Faculty Interviews. The 10 science faculty interviewed were very positive about the Meyerhoff Program. As one faculty member put it, “I think the Meyerhoff Program in many respects is a model program for recruiting students who are both minorities and really good.” Another noted, “The overwhelming majority, if not 100%, of the department is impressed and in favor of this program in its current form.”

Faculty members were asked to delineate any impact the program has had on their department and on the university. Two impacts emphasized were changed faculty expectations of African American science students, and ramifying effects on science at UMBC more generally. They also noted some potential negative aspects of the program.

Dramatic Change in Faculty Expectations of Black Student Performance. Most of the faculty interviewed reported a dramatic, positive change in perceptions and expectations concerning African American student performance in science as a result of the Meyerhoff Program. The first two quotes below are from faculty members who had been at UMBC many years prior to the start of the program; the third is from a faculty member who came to UMBC after the program had already been in existence several years.

"In the past, a student in your class who was Black was likely not to do well. The Meyerhoff program changed that almost immediately. As soon as Meyerhoff students started earning A's . . . becoming very insistent on going into research programs and being successful, all of a sudden you couldn't make that assumption. Looking for success rather than failure [in your Black students]. That's a big change. That's a big institutional change. That happened in my department and it happened throughout the institution."

"When the Meyerhoff Program first started, the top three students in the class are these Meyerhoff Scholars . . . African American students. I was shocked. I said, wow, this is really something. You know, there are brains everywhere."

"I've heard faculty say that before Meyerhoff the prejudice was always that a minority student would likely be a weak student. Now I think it's turned around to the point where a minority student is expected to be a high performing student."

The next quote describes a faculty member's experience with the Meyerhoff students in his advanced seminar.

"Half the [advanced elective seminar] would fill up with Meyerhoffs. They were all hanging together. They study together. They are all smart people. It's just amazing to see them."

Ripple Effect on Science at UMBC. A number of the faculty identified ramifying or ripple effects the Meyerhoff Program has had on science on campus more generally. The four quotes below emphasize, respectively, recruitment of non-Meyerhoff minority students, higher standards of class performance, Meyerhoffs as role models in the lab, and the developing multicultural composition of science at UMBC.

"The minority students who don't get into the program still want to come to our campus because they want to be around that type of person. They just want to be surrounded by minorities that care about education and are driven and trying to be the best people they can be."

"The Meyerhoff students want to perform. They want to get that A. It enhances everybody's performance who cares about the course."

"In the research lab . . . they are role models for [other minority students.]"

" . . . A large number of Black kids who are interested in science—it's a good change. It's different. It's part of the whole multicultural environment."

Potential Negative Impacts. Although each faculty member interviewed spoke positively about the influence of the Meyerhoff Program on their department, a number also identified some potential negative impacts. These focused primarily on ways in which the program affected students not in it. The first three quotes below emphasize feelings of jealousy and exclusion that the program may engender in some students.

"I wonder how common it is for gifted young non-Meyerhoff Black kids to feel that somehow they don't have the same status."

"Fifteen percent of [UMBC science] students are the high performers. Of that 15%, 1% maybe are Meyerhoff students. The school goes out of its way to recognize them. [But] the other 14% are not in the Meyerhoff Program. These people need to be recognized. This is a negative aspect. It's not that you don't want to publicize the Meyerhoff, but you want to recognize that the bulk of our really good students are not in the Meyerhoff."

"We have students that are borderline, that don't get in. [The Meyerhoff Program may motivate some of these students] to go forth and do better and see what they can achieve [but] other people may develop jealousy about it, a very negative emotion to have."

Finally, related to the above concerns, several faculty emphasized their desire that all UMBC science students eventually receive the services that the Meyerhoff Program provides its students.

"If [the program] has a negative effect on other students, I think it is that some students may feel overlooked. You can argue that after 200 years of discrimination, maybe that's okay for 50 or 60 years to go the other way. But I personally would like to see that we could expand to other groups."

"The time management and support system that has been developed in the Meyerhoff Program I think helps these students a lot, to perform highly. I think that many of us wish that we could expand it to non-minorities. Provide the same services to other groups."

Summary of Process Evaluation Findings

The process evaluation surveys pointed to a number of Meyerhoff Program components that appear especially important contributors to program effectiveness, including Program Community, Study Groups, Summer Bridge Program, Financial Support, Program Staff, Research Internships and Mentors, and Campus Academic Environment. The process evaluation interviews suggested some of the ways the components contribute to academic performance, indicated areas of additional program impact, and revealed several areas of potential concern.

Discussion

The achievements of the Meyerhoff students at the University of Maryland, Baltimore County provide evidence that a well-designed university-based intervention can increase the numbers of African American undergraduate college students who succeed in science, mathematics, and engineering. The Meyerhoff students were more likely to graduate in an SEM major, earn competitive SEM grade point averages, and enter SEM graduate programs than multiple comparison samples. Prior research has identified problems facing African American students in predominantly white universities, and in SEM majors, such as academic and social isolation, the weed out system, low faculty expectations, negative stereotype vulnerability, and perceived racism. These help explain why highly accomplished and bright African-Americans do not succeed in SEM majors (cf. Tinto, 1987; Nettles, 1988; Steele and Aronson, 1995; Seymour & Hewitt, 1997). Informal interviews conducted by the second author with well-qualified UMBC African American SEM majors in the years immediately preceding the development of the Meyerhoff Program indicated that they indeed often had comparable experiences. The process data collected over the past 7 years support the hypothesis that the Meyerhoff Program works because its components provide opportunities for overcoming these problems—by enhancing academic and social integration, knowledge and skill development, support and motivation, and monitoring and advising.

Academic and Social Integration

The Meyerhoff Program contributes to student academic and social integration in a number of ways. An intensive summer bridge program, and the fact that students live together in the same residence hall freshman year, help to build from the start a sense of connectedness and interdependence. Ongoing participation and membership in a peer community composed of like-minded, high achieving African American students deepens levels of social bonding, academic relatedness, and cultural rootedness. Study groups, program-wide meetings, and cultural events represent some of the specific participatory mechanisms contributing to academic and social integration. The accessibility and high levels of involvement of program staff, and of science faculty and university administrators (President's Office), appear to contribute powerfully as well.

Knowledge and Skill Development

The Meyerhoff Program contributes to knowledge and skill development through multiple channels. As a foundation for what is to follow, the intensive program recruitment process helps to ensure that students who enter the program have strong academic preparation, along with a commitment to pursue SEM majors. The summer bridge program's mathematics and science coursework, along with training in analytic problem solving and time management skills, provides a head start and conceptual underpinnings for later knowledge and skill development. Participation in program study groups, and the utilization of tutoring resources, contribute directly to strong course performance. In addition, Meyerhoff students have developed a test bank and a repository of class notes for key science courses to facilitate course content mastery and successful course outcomes.

Support and Motivation

The Meyerhoff Program can be viewed in part as a multifaceted, multilevel support and motivational system. Program scholarships free students from the need to take time away from academic pursuits in order to earn money, and simultaneously motivate students to perform well in their science courses, since scholarship continuation is contingent upon maintaining at least a B average in an SEM major. Key program values serve as a major source of motivation—emphasizing outstanding academic achievement, seeking help (tutoring, advisement counseling) from a variety of sources, supporting one's peers, and preparing for graduate study. These messages are consistently conveyed and reinforced in both public and private contexts, by program staff, by the university president (the program's founder), and by program peers. Summer research internships, many at prestigious national and international sites, along with research mentoring relationships developed with UMBC faculty, serve to further motivate students to achieve at high levels and pursue graduate study, and embed students in a network of social contacts and connections which directly contributes to such goals.

Monitoring and Advising

Meyerhoff Program staff intensively monitor students' progress each semester, sensitive to warning signs of academic or personal problems. As a result, emerging problems can be addressed quickly. The monitoring by program staff takes place through contact with both faculty and students—the latter occurs in the context both of formal meetings and informal social and cultural activities. Action plans generated to address problems start with the individual, but may expand to involve family, peers, and faculty.

The program employs its own academic advising staff, so that the Meyerhoff students receive specialized and in-depth academic advising on a regular basis. Students also benefit from advice offered by more advanced students in the program. Monitoring and advising begin with the summer bridge program, and continue throughout the student's undergraduate years, and includes a strong focus on preparation for graduate study. The intensive nature of monitoring and advisement, combined with high expectations for both academic performance and personal conduct, may sometimes leave students feeling a lack of privacy and a strong sense of pressure, as revealed in some of the interview excepts cited above. On the other hand, the advising and monitoring system increases the odds that major problems will be prevented or detected early enough to limit their impact, and helps to ensure a successful trajectory through the many stresses and challenges of college life in general and of demanding SEM majors in particular.

Research Basis and Program Generalizability

As reviewed earlier, extant research supports a link between the factors discussed above, addressed in various ways by the Meyerhoff Program, and minority student performance. The importance of academic and social integration for minority student success in SEM majors is consistent with the work of a number of theorists and researchers (e.g., Tinto, 1987; Nettles, 1988; Hilton et al., 1989; Allen, 1992; Seymour & Hewitt, 1997). Research supports the potential of various pedagogical strategies to enhance knowledge and skill development, such as the use of study groups to master difficult SEM material (Treisman, 1992; Bonsangue & Drew, 1995; Kosciuk, 1997). The centrality of a multifaceted support and motivational system encompassing financial, peer, and faculty components is consistent with available empirical research (Hilton et al., 1989; Seymour & Hewitt, 1997; Gandára & Maxwell-Jolly, in press). Finally, the importance of systematic monitoring and advising builds upon knowledge in the student advising and counseling area (cf., Glennan et al., 1985; Seymour & Hewitt, 1997; Gandára & Maxwell-Jolly, in press). Of note, a number of other nationally prominent SEM programs employ some of the same program elements as the Meyerhoff Program to influence the factors which influence minority student performance (cf. Gandára & Maxwell-Jolly, in press).

In the case of the Meyerhoff Program, the synergistic influence of these elements in a truly comprehensive program effort likely contributes to the striking program effectiveness observed. Such strong outcomes might not be possible if only a selected few, but not the full range, of key program components were present. This hypothesis is clearly an important one in need of future research.

Also of special note, the high level campus administrative support the Meyerhoff Program enjoys appears to be a critical component that has made a substantial difference in the implementation and ongoing effectiveness of the program at UMBC. It remains unclear to what extent intervention programs to improve minority performance and persistence in science can succeed when high level university administrators are not actively involved.

Limitations of the Study

The Meyerhoff Program appears to be among the nation's top producers of African American college graduates who enter SEM graduate programs (Brazziel & Brazziel, 1997; National Task Force on Minority High Achievement, 1999), and there has been a significant increase in the number of students graduating and entering graduate school since the three cohorts examined in this study. However, entering graduate school is only a beginning. The long range goal of the Meyerhoff Scholarship Program is to produce substantially more African American Ph.Ds in science, engineering, and mathematics. Although we have documented that the Meyerhoff students are more likely to enter these graduate programs than are comparison groups, not enough time has elapsed to determine the number and percentage of students who complete doctoral degrees. To date, informal contact with students in these graduate programs indicates that many are making good progress, such as completing doctoral coursework, passing comprehensive exams, and becoming actively involved in dissertation research. We recently initiated a study to systematically document the graduate school experiences and outcomes of these students. An additional area of needed research, one currently in the planning stage, is the "spillover" effect of the program on non-Meyerhoff minority students and on science at UMBC, areas of impact suggested by some of the faculty interviewed.

The discussion above assumes that the Meyerhoff Program accounts for the students' success at UMBC. There are, however, alternative explanations. The in-depth selection process in the recruitment component of the program may yield students whose personal characteristics would ensure their success anywhere. Alternatively, students who are not willing to make this commitment may self-select out of the program, once faculty, staff, and administrative personnel make it clear that they are expected to achieve, persist to graduation and enter SEM doctoral programs. (Of note, however, the first year coursework of the students in the "declined" sample suggested their intent to pursue SEM majors.)

Furthermore, Elliot et al. (1995) believe that persistence and achievement in SEM programs are a function of a student's relative academic talent (operationalized as the SAT-Math score) compared to the other students at his or her university. They specifically suggest that Meyerhoff student scores are all among the top tercile of SAT-M scores at UMBC, virtually guaranteeing the students will graduate in their SEM major at this institution. In fact, although they are among the best students at UMBC, approximately 15% of Meyerhoff students do not have SAT-M scores in the top tercile of UMBC students. Importantly, this subgroup of students graduated in SEM majors at approximately the same rate as those in the highest tercile. In addition, White and Asian SEM majors, those with whom the Meyerhoff students most directly compete, have higher SAT-Math scores than do students in other majors at UMBC. When compared only to other SEM majors, approximately 5% of the Meyerhoff students are in the bottom tercile, 33% are in the middle tercile, and the remaining 62% are in the top tercile. Once again, a comparison of student graduation rates found virtually identical rates across all Meyerhoff tercile groups. A similar analysis of the Declined sample also does not support Eliot et al.'s hypothesis. Declined sample students with high SAT-M scores at less selective institutions were no more likely to graduate in SEM majors than were students with mid-level scores at very selective universities.

In summary, while we believe that the recruitment process and the relative position of the Meyerhoff students at UMBC may account in part for their success, we do not believe that they would achieve and persist at the current levels without the Meyerhoff Program. Indeed, the findings of lower academic outcomes from multiple comparison samples, together with the process evaluation findings, provide compelling evidence that the Meyerhoff Program accounts, at least in part, for African American student success in SEM majors at UMBC.

Conclusions and Implications

It remains abundantly clear that the roots of the science pipeline "problem" for African American students are in the often poorly funded, de facto segregated, inner-city schools that many attend, and the less than competitive programs into which many blacks are tracked in suburban integrated schools. Although less well documented, this may be augmented and exacerbated by expectancy effects in the teacher–child interaction (cf. Rosenthal, 1994). Support for this hypothesis lies in the studies showing that even those African American students with math and science standardized test scores at the elementary school level similar to White counterparts, over time fall behind White children in these skills. By the time they reach high school, the gap has become wide enough that a smaller proportion of African American students are qualified to attend SEM programs in college (Gandára & Maxwell-Jolly, in press). Beyond schools per se, another extremely important factor is the family, which can have a critical impact on African American students' educational preparation, aspirations and success (Hrabowski, Maton, & Greif, 1998; Hrabowski, Maton, Greif, & Greene, in preparation).

The overall effect of substandard pre-college education has been a smaller pool of African Americans qualified for college work in SEM curricula. This is manifest in the lower number of African American SEM majors (Astin, 1993, noted that SAT-M scores are positively correlated with a student's intention to major in SEM) and their lower persistence rate (numerous studies document a positive relationship between SAT-M scores and achievement and persistence in SEM curricula).

At the college level, even the most talented African American students may experience enough environmental discomfort on majority white campuses to depress their academic performance. Research is widely divergent, but common discomfort themes involve SEM ''weed out'' systems, a sense of isolation in the sciences, negative stereotypes, low faculty expectations, and perceptions of racism. These issues make it more difficult for African American students, however bright they may be, to persist and perform at high levels in SEM fields.

Greater efforts should be made at the university level to ensure that promising African American students remain in SEM majors and become the next generation of researchers and mentors (cf. Gandára & Maxwell-Jolly, in press). This is especially critical given the recent reductions in minority entrance into SEM graduate programs, presumably due in part to perceptions of negative views toward minorities (i.e., anti-affirmative action efforts) in a number of states (cf. Malcolm, Van Horne, Gaddy, & George, 1998). Programs like The Meyerhoff Scholars Program, built on extant social science research, may be especially important for African American (and other minority student) success in the science, engineering and math disciplines in the years ahead.

Support for the research reported in this article was provided by grants from the National Science Foundation and the Alfred P. Sloan Foundation. The authors appreciate the contributions of Tracey Drummond, Sharon Fries-Britt, Troy Green, Monica Greene, Kerina Rutter, Julie Sakin, and Wendy Stevenson to the conduct of the research, and the ready willingness of the Meyerhoff Scholars to serve as research participants.

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