American Institute of Physics

TEAM-UP REPORT

THE TIME IS NOW

Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy

TEAM+UP

THE TIME IS NOW

Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy

The AIP National Task Force to Elevate African American Representation in Undergraduate Physics & Astronomy (TEAM-UP)

American Institute of Physics
College Park, MD

www.aip.org

To request additional copies of this book, contact:

AIP/TEAM-UP
1 Physics Ellipse
College Park, MD 20740

+1 301.209.3100
www.aip.org/teamup

International Standards Book Number: 978-1-7343469-0-9

Printed in the United States of America

AIP | American Institute of Physics

AIP | American Institute of Physics

The American Institute of Physics is a federation that advances the success of our 10 Member Societies and an institute that operates as a center of excellence supporting the physical sciences enterprise.

Over the last 400 years, the physical sciences have evolved a powerful predictive model of our world, enabling stunning technological achievements and enriching our understanding of the Universe and our place in it. AIP has, for nearly a century, worked to advance, promote, and serve the physical sciences.

AIP provides the means for its Member Societies to pool, coordinate, and leverage their diverse expertise and contributions in the pursuit of the shared goal of advancing the physical sciences in the research enterprise, in the economy, in education, and in society. Through their partnership in AIP, Member Societies broaden their impact and achieve results beyond their individual missions and mandates.

AIP also acts as an independent institute where research in social science, policy, and history advances the discipline of the physical sciences.

In this regard and from time to time, AIP issues an Expert Report—that is a report of the Institute authored by a panel of experts appointed to conduct a study to answer specific sets of questions. The resulting Expert Report includes findings and recommendations based on data and information gathered by and deliberated on the panel. The resulting peer-reviewed report presents the evidence-based consensus of the panel of experts and represents AIP's position on the questions contained in the panel's charge.

This report is an Expert Report of the American Institute of Physics and was accepted as such by the AIP Board of Directors on November 13, 2019.

TEAM-UP Co-Chairs:

Mary James
A. A. Knowlton Professor of Physics & Dean for Institutional Diversity
Reed College

Edmund Bertschinger
Professor of Physics, Former Institute Community & Equity Officer
MIT

TEAM-UP Task force Members:

Brian Beckford
Presidential Postdoctoral Fellow/Asst. Physics Prof., Univ. of Michigan

Tabbetha Dobbins
Associate Professor of Physics, Rowan University

Sharon Fries-Britt
Professor of Higher Education, University of Maryland College Park

Sylvester James Gates
Ford Foundation Professor of Physics, Brown University

Jedidah Isler
Assistant Professor of Physics & Astronomy, Dartmouth College

Maria Ong
Senior Research Scientist, TERC

Arlisa Richardson
Residential Physics Faculty, Chandler-Gilbert Community College

Quinton Williams
Chair and Professor of Physics, Howard University

Philip W. “Bo” Hammer
Senior Director, American Institute of Physics

A**rlene Modeste Knowles**
TEAM-UP Project Manager, American Institute of Physics

Contents

Acknowledgments

TEAM-UP undertook an ambitious two-year study that would not have been possible without the help and expertise of several people and organizations. We thank the Liaison Committee on Underrepresented Minorities of the AIP, who recognized the need for this study and provided its charge. We would like to thank the staff of the AIP Statistical Research Center and the Higher Education team at the University of Maryland (named below) led by Dr. Sharon Fries-Britt of TEAM-UP and Dr. Alberto F. Cabrera for bringing their scholarly expertise to the development and execution of the TEAM-UP student survey and student interviews, for providing rigorous analysis, and for informing the Task Force throughout its work. We thank Dr. Simone Hyater-Adams (former graduate student at the University of Colorado Boulder) for her excellent work on the TEAM-UP literature review, and Christina Bebe (former TERC student intern and Simmons University undergraduate student) for compiling resources for the report; both were supervised by and collaborated with TEAM-UP member, Dr. Maria Ong (TERC). We are also deeply appreciative of the physics chairs, faculty, students and administrators at Chicago State University, Georgia State University, Henderson State University, Morehouse College, and the University of Maryland, College Park, for generously opening up their departments and sharing their practices and experiences with the TEAM-UP site visit teams. The significant contributions of all of these individuals to the TEAM-UP study were invaluable to the research and instrumental to the success of this project.

Special thanks to all those who helped to facilitate the work of TEAM-UP including Dr. Renee Horton and Dr. Willie Rockward, former and current Presidents of the National Society of Black Physicists, who allowed TEAM-UP to publicize our surveys at their conferences and conduct student interviews at their 2018 conference. NSBP has been an important partner in the TEAM-UP project and we are very appreciative of their continued support. Thank you to Shirley Malcom who wrote a wonderful foreword to this report and has been a tireless advocate for STEM equity throughout her long career at AAAS. We appreciate her support of TEAM-UP throughout its duration.

Thank you also to all who graciously agreed to publicize and distribute our student survey to their professional and student members including: Dr. Eman Ghanem, Dr. Jamie Vernon, and the team at Sigma Xi; Dr. Beth Cunningham and Dr. Robert Hilborn at the American Association of Physics Teachers (AAPT); Dr. Monica Plisch and the American Physical Society (APS) diversity staff; Dr. Garfield Warren (Indiana University) and the physics REU site directors; Dr. Brad Conrad and the Society of Physics Students/Sigma Pi Sigma staff; the HBCU physics department chairs; and countless others who distributed the survey through social media.

We also thank the report reviewers for the time they contributed to review the first draft of the report and provide meaningful feedback that has resulted in a much stronger and hopefully more impactful report.

TEAM-UP owes particular gratitude to the Board, officers, and staff of the American Institute of Physics for their generous support of this effort. We especially thank Laura Merner, Patrick Mulvey, Susan White and Rachel Ivie (formerly) from the Statistical Research Center for their support in TEAM-UP's research and analysis, and the Marketing, Communications, and Media teams. We also gratefully acknowledge and thank the Research Corporation for Science Advancement for their partial support of the research phase of the TEAM-UP project.

Finally, and most importantly, we owe a debt of gratitude to the students who participated in the TEAM-UP study through surveys and interviews. We thank you for openly and honestly sharing some of your most heart wrenching stories with us, but also stories of determination and triumph, which give us hope. This report is meant to tell your stories, center your experiences, and inspire the physical science community to improve in ways that support your success in earning your physics and astronomy degrees.

University of Maryland, College Park
Higher Education Researchers

Dr. Alberto F. Cabrera
Professor, Higher Education

Dr. Sharon Fries-Britt (TEAM-UP member)
Professor, Higher Education

Nacie Grigsby
Master's Student, Higher Education

Dr. Elizabeth Kurban
Assistant Director for Retention, Clark School of Engineering

Nemeka Mason-Clercin
Doctoral Student, Higher Education

Donté McGuire
Doctoral Candidate, Higher Education

Briana O'Neal
Doctoral Student, Higher Education

Felicia James Onuma
Doctoral Student, Higher Education

Foreword

Shirley Malcom, AAAS

In 2006 I was honored to have been invited to contribute an article to *Physics Today.* "Diversity in Physics" explored the continuing challenge within the physics community to attract women from all racial/ethnic groups and African American, American Indian, and Hispanic men to the field. That issue of the journal https://physicstoday.scitation.org/toc/pto/59/6 included a collection of articles that looked back at the world of physics in the 75 years since the founding of AIP and those that peeked over the horizon to what might lie ahead.

In the ensuing years since writing that article, many things have changed; but unfortunately, some things have not. In the period between 2006 and 2016, among U.S. citizens and permanent residents, African Americans received between 7 and 8 per cent of chemistry bachelor's degrees, between 5 and 6 per cent of bachelor's degrees in mathematics and statistics and between 9 and 12 per cent of such degrees in computer science. While most of these numbers are unacceptably low and not reflective of students' presence within the college going population, the story for physics is particularly depressing.

The report from TEAM-UP points out that the stubborn challenges of under participation by African Americans within physics remain. For bachelor's degrees in physics for African Americans, the needle has hardly moved since 2006.

Both the 2006 article and this report from the comprehensive TEAM-UP study point to the need for systemic change. The TEAM-UP report not only lays out the case for change, but also incorporates important research that points to the roles that the physics community needs to play at every level. It calls for **actions** at every level and for a specific timeline and targets.

The physics community has demonstrated its capacity time and time again to come together in addressing important societal issues, such as its active engagement within the Societies Consortium on Sexual Harassment in STEMM and its development of department level transformation initiatives within SEA Change to support diversity, equity and inclusion.

The TEAM-UP report points the way toward an aggressive and achievable path forward, a path that aligns with and supports the work of both the Societies Consortium and SEA Change. Drawing on important social science research as well as its own robust statistical and qualitative analyses, the report points to the need for a multi-pronged approach to support inclusion of African American men and women in physics. It should be reassuring that other research on the broader problem of marginalization and weeding out in STEM programs tracks with the findings and recommendations of the TEAM-UP report.

While predominantly white institutions (PWIs) now enroll most African American physics students, HBCUs still play an outsized role in terms of physics bachelor's degree production. A number of policy questions arise from this finding. For example, can we make a case for higher levels of support for physics programs at HBCUs, with more partnerships and opportunities for undergraduate research? Should physics programs at PWIs be required, within funding proposals, to articulate diversity plans that speak to incorporation of policies, programs, practices, instructional strategies, etc. of demonstrated effectiveness in advancing education and degree completion by African Americans students? How do we support efforts to incorporate the knowledge, support and the will exhibited by historically and predominantly black institutions within physics programs at PWIs? What role might there be for national labs and federally funded centers to support career interests and funding for African American students?

The action plan outlined in the TEAM-UP report is a great place to start in building out a community-wide strategy.

The 2006 article included an observation supported by research that I raise again here, as I noted how very young children experience and learn about the physical world through play and social interaction.

"How do children move from behaving in ways that are so clearly consistent with learning about the physical world to avoiding courses that can support their understanding of it? Put a different way, how does physics move from being an inclusive domain for learning to an exclusive or exclusionary one?"

How do we take advantage of demonstrated interest to keep African American students in the talent pool for physics, to nurture their interest, to make them feel welcomed and accepted, to engage and support their learning? Those are the challenges and the opportunities for the physics community.

Shirley Malcom, PhD, is a senior advisor at the American Association for the Advancement of Science (AAAS) and director of STEM Equity Achievement (SEA) Change, an initiative that supports institutional transformation in diversity, equity, and inclusion. She has served as Head of Education and Human Resources Programs at AAAS for nearly 30 years, and is a trustee of Caltech, and Regent of Morgan State University. Malcom formerly served on the National Science Board and on President Clinton's Committee of Advisors on Science and Technology. In 2003, she received the Public Welfare Medal of the U.S. National Academy of Sciences, the highest award given by the Academy. Malcom is a Fellow of AAAS and of the American Academy of Arts and Sciences, and serves on the boards of the Heinz Endowments, Public Agenda, NMSI and Digital Promise.

Malcom holds BS and MA degrees in zoology from the University of Washington and UCLA, respectively, and earned her PhD in ecology from Penn State.

Reader's Guide to the Report

This report is unusual in many ways for the physical sciences. First, it was researched and written by a team of physicists, astronomers, and social scientists, collectively called TEAM-UP. Second, while it presents data and draws conclusions, as a research publication does, it is also full of quotes from students. It discusses at length concepts like belongingness and change management, which may seem far removed from physics and astronomy research to some. In fact they are *not* removed from these subjects, because *who* does research depends on who *belongs*, and on whether *change* occurs to diversify the disciplines. TEAM-UP members firmly believe that scientists cannot solve the problem of African American underrepresentation using methods common to physics and astronomy; new thinking and new language are needed. Consequently, this report is unlike any strategic plan a physicist or astronomer is likely to produce for their field; it emphasizes changing how we think, rather than changing processes and outcomes. In other words, this report aims to shift the cultures of the physics and astronomy communities in order to improve outcomes for African American students.

The report is organized as follows. The Executive Summary, which follows this guide, presents the thematic structure that emerged from our research and summarizes findings centered on the experience of African American students. The findings lead to a set of recommendations for individual faculty, departments, and professional societies. The full findings and recommendations are summarized in the last chapter, followed by a Glossary introducing and defining many terms used in the report that may be unfamiliar to some readers. Readers may skim the Glossary to determine their readiness for the main chapters.

The main research findings and recommendations are presented in the chapter Supporting Student Success. Organized by the five factors highlighted in the Executive Summary, this chapter presents the research case and describes many effective practices observed in TEAM-UP site visits. The findings are drawn from TEAM-UP and extant research; each finding leads to a recommendation. Additional recommendations are made as a result of the interactions among individuals, departments, colleges and universities, and professional societies.

The student chapter is followed by A Call to Action, which places the problem addressed by this report, the underrepresentation of African Americans in undergraduate physics and astronomy, in a broader societal context. This chapter also discusses the need for a highly developed understanding of institutional change and provides relevant recommendations. Finally, it presents a bold vision for how the physics and astronomy communities might inspire others to emulate their efforts. In many ways, this chapter is the most important one of the report. TEAM-UP determined that methods and results from the social sciences are essential to solving the problems of underrepresentation in physics. This concluding chapter is a fast-paced introduction that should be followed by further study and sensemaking.

A set of appendices provides detailed background on our methodology as mentioned in the Introduction. Additionally, three appendices were created specially to help students and departments: Appendix 8 is a self-assessment rubric for departments, Appendix 9 is a rubric for high school students and their parents to evaluate prospective physics and astronomy departments, and Appendix 10 is a resource guide for students, faculty, and others working to advance racial equity in the physics and astronomy professions.

The goal of this report is to motivate the key stakeholders within and outside the physics and astronomy communities to work together to systematically increase the number of African American students earning bachelor's degrees in physics and astronomy, and to inform and guide them in this effort. Although this report was written for and researched about the physics and astronomy disciplines, the relevant research literature spans all the STEM (Science, Technology, Engineering, and Math) fields, and the report may be useful in guiding research and practice in these fields too.

TEAM-UP invites the physics and astronomy communities to read this report carefully, acknowledge that there is room for improvement within their programs to support African American students, and consider how they might begin to implement the recommendations found herein. Most of the recommendations are already being followed in several of the top-performing departments we visited.

Executive Summary

During 2018 and 2019, TEAM-UP, the National Task Force to Elevate African American representation in Undergraduate Physics & Astronomy, examined the reasons for the persistent underrepresentation of African Americans in physics and astronomy in the US as measured by bachelor's degrees in these fields. The task force was chartered by the Board of Directors of the American Institute of Physics and charged with producing a detailed report and recommendations.

To determine the key factors supporting or diminishing student success, TEAM-UP conducted a major research study that included student surveys, department chair surveys, interviews with African American students, and site visits to five high-performing physics departments. In addition to these data collection efforts, the task force reviewed the research literature and received input from several hundred individuals to guide the work. This report combines original research with a review of the research literature to provide a set of research-based findings and recommendations.

TEAM-UP identified five factors responsible for the success or failure of African American students in physics and astronomy: Belonging, Physics Identity, Academic Support, Personal Support, and Leadership and Structures. In the body of the report, each factor is supported by four research findings and four corresponding recommendations for individual faculty, departments, and/or professional societies. A fifth recommendation is made for each major factor to address the interactions among individuals, departments, colleges and universities, and professional societies. The recommendations are far-reaching and challenging, requiring philosophical and practical changes in the way the community educates and supports students. To support the adoption of the recommendations, the report provides an additional set of five recommendations on Change Management. Together, the five factors and the topic of Change Management provide six themes around which this report is organized.

The task force finds that African American students have the same drive, motivation, intellect, and capability to obtain physics and astronomy degrees as students of other races and ethnicities. Many African Americans who might otherwise pursue these fields are choosing majors that are perceived as being more supportive and/or rewarding, resulting in a loss of talent to physics and astronomy.

The briefest summary of the TEAM-UP report is this: the persistent underrepresentation of African Americans in physics and astronomy is due to (1) the lack of a supportive environment for these students in many departments, and (2) to the enormous financial challenges facing them and the programs that have consistently demonstrated the best practices in supporting their success. Solving these problems requires addressing systemic and cultural issues, and creating a large-scale change management framework.

The overarching goal of this report is to at least double the number of bachelor's degrees in physics and astronomy awarded to African Americans by 2030. This report calls on departments and professional societies, working with funding agencies, foundations, and donors, to commit to achieving this goal. Every recommendation in this report is a means to this end.

Below is a summary of the task force's key findings and recommendations, organized by the five factors responsible for the success or failure of African American students in physics and astronomy and the sixth topic of change management. It starts with factors that are the most centered on the individual student and ends with those reflecting the broadest academic context. The highest priority recommendations are identified at the end of the Executive Summary. The full set of key findings and recommendations is given in the last chapter.

FACTOR 1: BELONGING

Fostering a sense of belonging is essential for African American student persistence and success.

A sense of belonging is defined as an individual's feeling of being a welcomed and contributing member of a community. TEAM-UP's research on the student experience shows that fostering a sense of belonging is essential for African American student persistence and success. Faculty and peer interactions have a powerful effect on students' sense of belonging, which increases with the number of faculty who get to know students as individuals and demonstrate support for their success. Student peers play a role in mitigating or exacerbating African American students' sense of not belonging, through microaggressions, the imposter phenomenon, and stereotype threat.[1] Peers of the same race/ethnicity/gender provide valuable social and academic supports, often through counterspaces.

The recommendations around belonging emphasize the faculty role in fostering a sense of belonging for students but also note the essential roles that departments and professional societies play. In summary, TEAM-UP recommends that departments support faculty in improving and practicing skills that promote students' sense of belonging. Departments should establish and consistently communicate norms and values of respect and inclusion through policies, physical spaces, programmatic offerings, and all forms of communication with students. Professional societies should pursue coalition-building efforts that seek to address and eliminate identity-based harassment including microaggressions and acts motivated by bias and racism.

1 These and other technical terms are defined in the Glossary.

FACTOR 2: PHYSICS IDENTITY

To persist, African American students must perceive themselves, and be perceived by others, as future physicists and astronomers.

Physics identity is defined as how one sees oneself with respect to physics as a profession.[2] It evolves with one's perception and navigation of experiences within physics, including recognition by others. How students perceive themselves with respect to physics is predictive of career intentions and achievement. Here too, faculty play an important role in helping shape physics identity among African American students, who have already had to contend with and overcome stereotypes about who is interested in or capable of becoming a physicist or astronomer. TEAM-UP found that faculty encouragement, recognition, and representation are key enablers of physics identity. Physics identity is strengthened in African American students when they have same-race role models in the faculty, are routinely invited and financially supported to participate in the established activities of the profession, and are able to connect their physics education to activities that benefit their communities.

The TEAM-UP recommendations provide departments with the means to create a strong sense of physics identity in their students. Departments should take a strategic approach to building physics identity in students by determining whether current activities foster physics identity, assessing their efficacy across race/ethnicity/gender and other social identities, and using evidence-based strategies to modify those activities as necessary. Departments should also work to diversify their faculty across race/ethnicity/gender and other social identities. Departments and faculty should utilize resources, such as the AIP Careers Toolbox and African American alumni, to discuss a broad range of career options with undergraduates and communicate the ways in which physics and astronomy degrees empower graduates to improve society and benefit their community.

FACTOR 3: ACADEMIC SUPPORT

Effective teaching and a strengths-based approach to academic support are necessary for African American student retention and success.

Academic support is perhaps the first topic many physics faculty think of when considering how to address the underrepresentation of African American students, since providing such support is traditionally regarded as the responsibility of those who educate students. Indeed, effective teaching, mentoring, and student-centered support are important for retention and success of African American students, as they are for all students. However, it is a damaging myth that minoritized students—members of underrepresented groups who are marginalized in society—have, as a consequence of their identity, learning challenges or needs, and that if they work harder to bridge those gaps, they will achieve greater success. This sentiment, whether intentional or not, is played out every day on virtually every level, from interactions with peers to those with faculty and beyond. TEAM-UP site visits and the research literature show that recognizing student capabilities and building

2 Astronomy identity development is important, too, but unlike physics identity, it has not yet become a commonly used term in the education research literature.

on their strengths lead to better outcomes than focusing on their presumed weaknesses. Further, faculty who teach well, care about students, and demonstrate commitment to them by affirming their academic abilities, encouraging their success, and helping them find additional academic resources when needed, are critically important in fostering student success. Advising systems contribute to retention by providing early warning of student difficulties and allowing timely intervention. Providing multiple pathways into and through the major helps to recruit and retain African American students.

TEAM-UP's recommendations for academic support strengthen the services that departments are expected to provide to students—teaching, mentoring, and advising—with a focus on African American student success. Departments should encourage and support new faculty in improving teaching and mentoring by attending campus workshops or those provided by professional societies and other organizations. They should also adopt policies and practices that encourage faculty, including those who are not members of marginalized groups, to formally and informally mentor students, and should provide recognition and rewards for these efforts. Faculty and staff undergraduate advisers should work closely with campus advising offices to provide cohesive support and comprehensive resources for students facing academic or other difficulties, and departments should ensure that all students are aware of support services. Finally, departments should regularly assess their activities and curricular pathways from recruitment through degree attainment, identify points at which students leave or stop out before graduation, and develop evidence-based action plans to increase student persistence.

FACTOR 4: PERSONAL SUPPORT

Many African American students need support to offset financial burdens and stress.

Colleges and universities provide students with many kinds of support in addition to academic support. African American students often face challenges that require assistance from non-faculty experts, and awareness and referral by faculty can improve students' utilization of these resources. TEAM-UP research identified financial challenges as one of the greatest difficulties facing African American students. These financial stressors, much like a lack of academic support, can lead to increased need for mental health care and a greater risk of students leaving the major or school. Student retention improves when faculty recognize and respond to students as unique individuals with a wide range of intersecting social identities and acknowledge that their experiences of being minoritized in physics and astronomy departments may impact their academic performance. Access to jobs related to their major, such as paid research internships, help ease financial burdens and allow students to earn needed income while supporting their academic progress and reinforcing their physics identity.

Several of TEAM-UP's recommendations on personal support for students help faculty and departments navigate what may be unfamiliar or difficult territory. Faculty should seek funding for undergraduate students to work in research groups, and as Learning Assistants, for example, to help students advance academically while earning money. Similarly, departments should be aware of emergency and auxiliary financial aid and help students take advantage of these resources. Faculty should normalize seeking help for mental health needs by discussing self-care with students and pointing them to resources, and they should recognize the unique identity and promise of each student from a perspective of students' strengths rather than weaknesses.

The final recommendation within this category seeks to minimize the financial burden for African American physics and astronomy students in a larger way. A consortium of physical science societies should be formed to raise a $50M endowment to support minoritized students in physics and astronomy who have unmet financial needs. Half of the endowment income would go to direct support of African American physics and astronomy students and half would go to support departments' implementation of this report's recommendations and to support other financially marginalized groups in the future. As an interim step, physics and astronomy societies should raise $1.2M per year to relieve the debt burden of African American bachelor's degree students. The latter figure corresponds to the typical unmet need of $8K/year for 150 students, which is the number of additional African American students who should be earning physics bachelor's degrees at HBCUs (Historically Black Colleges and Universities) in order to achieve parity with the growth in physics degrees at Predominantly White Institutions since 1995.

FACTOR 5: LEADERSHIP AND STRUCTURES

For sustainability, academic and disciplinary leaders must prioritize creating environments, policies, and structures that maximize African American student success.

Effective departments create and sustain a supportive environment for their students. Department chairs play a key role in setting and acting on departmental priorities. Whether a department adopts the goal of increasing the number of bachelor's degrees awarded to African American students, and what steps it takes to support that goal, are functions of the leadership. Effective academic leadership utilizes committees, existing decision-making bodies, internal funding and other resources, and coalition building with campus programs and external organizations to effect change. Sometimes a singularly dedicated faculty member, or a lone champion, creates a supportive environment for African American students. However, evidence shows that the efforts of a lone champion are unsustainable. By contrast, in the most successful departments, a significant fraction of the faculty consistently value and support African American students as part of the department's culture and established practice.

In keeping with the findings, TEAM-UP's recommendations on Leadership and Structures advocate that department chairs set departmental norms and values of inclusion and belonging and that they actively partner with campus programs that provide scaffolding to support student belonging, STEM identity development, and personal and academic support of African American students. As well, department administrators should support and encourage students to utilize these important resources. Department chairs should also incentivize and reward multiple faculty members, including those who do not identify as faculty of color, to actively support underrepresented students. Professional societies should encourage relevant groups within their organizations to examine ways to advance the recommendations of this and similar reports.

CHANGE MANAGEMENT

A new level of thinking is required to solve a persistent problem.

The underrepresentation of African Americans in physics and astronomy is a systemic problem that cannot be solved through the isolated work of individual faculty, departments, or professional societies. It requires coordinating the efforts of stakeholders acting at all of these levels. In addition, standard approaches of strategic planning are unlikely to succeed because the underlying norms, values, and culture of the profession need to be addressed before lasting changes can occur. Fortunately, there is a growing body of literature on successful culture change in higher education to inform this work. This literature posits that preparatory work must be done prior to modifying processes toward a stated goal. First, a theory of change must be developed to guide the change process.[3] Effective change management considers the broader context for change and creates a shared understanding among key stakeholders of the need for and approach to creating the change.

3 A theory of change is a comprehensive description and illustration of how and why a desired change is expected to happen in a particular context

Professional societies have a leading role to play in this effort, as they did in the early 2000s with the SPIN-UP project, which succeeded in its goal to increase overall physics bachelor's degree production.[4] Professional societies and individual departments should each develop a theory of change around doubling the number of African Americans earning bachelor's degrees in physics and astronomy, utilizing sensemaking and shared leadership.[5] Representatives from all groups should jointly produce a unified change management model highlighting the interactions among the societies, universities, departments, and individual physicists and astronomers needed to support these efforts. Professional societies should facilitate these activities by holding discussion forums on this topic; empowering and preparing change agents through skill-building activities; and establishing recognition, rewards, and other incentives for efforts by faculty members to improve the success of African American students in physics and astronomy.

Finally, it is TEAM-UP's intention that this report not sit on a shelf but be used to inform, inspire, and serve as a guide toward real and lasting change. The last chapter of the report provides several means to encourage progress, including by recognizing the social responsibility of physicists and astronomers, and by providing assessment rubrics for high school students, parents, and faculty members, to evaluate departmental environments for African American students. Departments should review and learn from this report and the related reports and programs of other professional societies that address different aspects of diversity, equity, and inclusion. Professional societies and individual departments should gather relevant data about their organizations, disaggregated as appropriate by race/ethnicity/gender, and address disparities. All appropriate groups should begin to implement the recommendations found in this report, and an organizational body, to be determined, should assess and publicly communicate progress toward the recommendations of this report every two to four years, including quantitative and qualitative data similar to those used herein.

Priorities

We cannot emphasize enough the systemic nature of the problem under discussion: the persistent underrepresentation of African Americans in physics and astronomy is due to the lack of a supportive environment for African American students in many departments, and to the enormous financial challenges facing these students in general. Solving these problems requires changing not only the way physicists train students, but how they *think* about training students. The challenges are too difficult to be solved by individuals or even departments alone; physics and astronomy overall must be engaged through their professional societies. The solution requires both will and money.

Perhaps the first thing individual physicists and astronomers should do is consider their role in establishing their departmental cultures and commit to creating an environment where African American students and those from other marginalized communities can thrive. Consequently, this report's highest-priority recommendation is to read and discuss this and related reports (Recommendation 6b under Change Management). Professional societies, working with departmental representatives, should utilize sensemaking and shared leadership to develop theories of change for individual departments and professional societies and should also establish faculty networks, learning communities, and skill-building workshops (Recommendations 6a and 6c under Change Management). The APS Inclusion, Diversity, and Equity Alliance (APS-IDEA, Appendix 10) provides a framework for these efforts.

---

4 Indeed, SPIN-UP helped double the number of physics bachelor's degrees in just over a decade, thus demonstrating that a community-wide, goal-driven change effort can succeed.

5 Theory of change, sensemaking, and shared leadership each have a specific meaning in research on higher education. See the Glossary.

For professional societies, the first step is to support these change management processes and encourage existing and new groups within their organizations, such as the new APS Forum on Diversity and Inclusion, to examine ways to advance the recommendations of this and similar reports (Recommendation 5e). The second step is to raise substantial funding to support minoritized students with unmet financial need in physics and astronomy, and to support the implementation of this report's recommendations by departments (Recommendation 4e).

For department chairs, the highest priority is to identify campus and external resources that provide financial relief to students and help students with unmet needs take advantage of them (Recommendation 4a). Next is to begin the hard work of culture change by setting norms and values of inclusion and belonging; recruiting, developing, and supporting a diverse faculty; and overseeing structures, policies, and practices that enhance the success of African American students (Recommendation 5a).

After physicists and astronomers have understood the nature of the problem, they can begin to undertake actions addressing the five factors in student success (Belonging, Physics Identity, Academic Support, Personal Support, and Leadership and Structures). For individual faculty, the top priority should be to learn, practice, and improve skills that foster student belonging in their interactions with undergraduates (Recommendation 1a). The next priority for individual faculty is to seek funding for undergraduate students to work in research groups, as Learning Assistants (defined in the Glossary), or find other ways to help students advance academically while earning money (Recommendation 4b).

After undertaking these steps, individual researchers, department chairs and officers, and professional societies will be able to identify the next steps appropriate to their context from among the many other recommendations in this report.

Introduction

TEAM-UP, the National **T**ask Force to **E**levate African **Am**erican representation in **U**ndergraduate **P**hysics & Astronomy, was first proposed to the AIP Board of Directors in March 2017 by a committee of representatives from each of the 10 AIP Member Societies, the National Society of Black Physicists, the National Society of Hispanic Physicists, and the Society of Physics Students. This Liaison Committee on Underrepresented Minorities (LCURM) determined that one of the most critical issues facing the physics and astronomy community is the persistent underrepresentation of African Americans at the bachelor's level. LCURM recommended that a task force be appointed to study this challenge and issue a report with evidence-based recommendations for addressing it. The proposal for this two-year task force project was endorsed by all the societies represented on LCURM and was approved and funded by the AIP Board of Directors in June 2017.

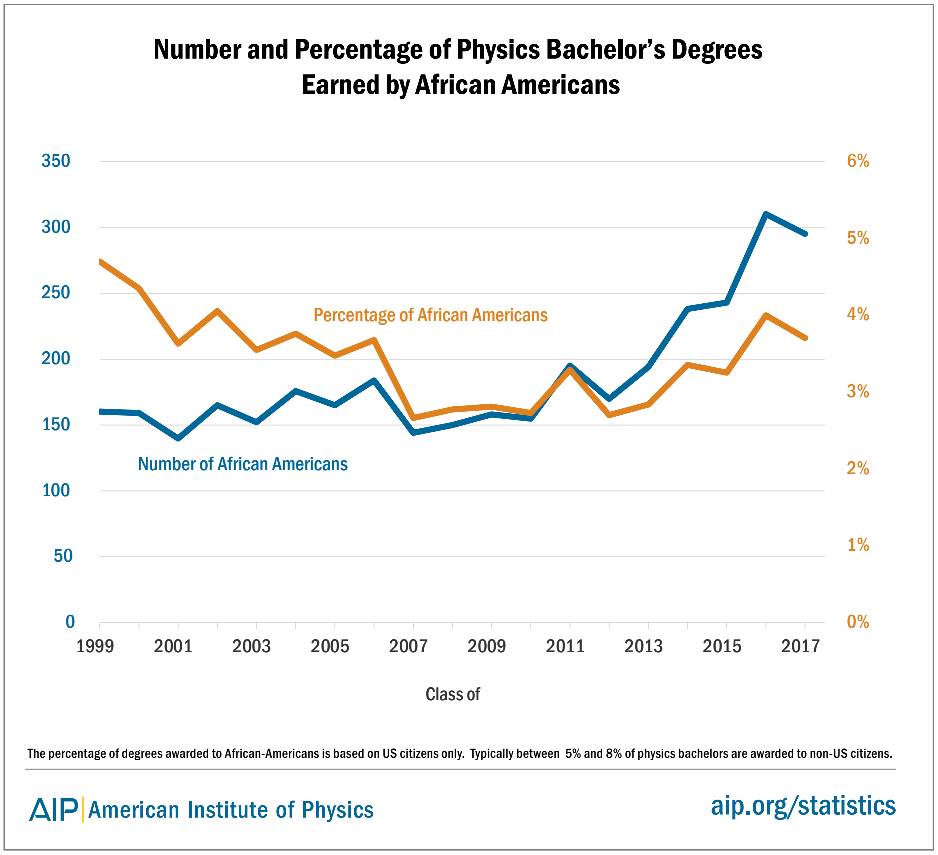


Figure 1: Number and Percent of Physics Bachelor's Degrees Earned by African Americans

There were several reasons why LCURM proposed that the task force focus specifically on African American participation in physics and astronomy at the bachelor's level. First, while there is widespread acknowledgment that physics and astronomy must improve diversity, equity, and inclusion overall, the number and percentage of bachelor's degrees awarded to African Americans in these fields has been appallingly low, dropping from about 5% in the late 1990s to less than 4% in recent years (Figure 1). Furthermore, over the past 20 years, the overall number of bachelor's degrees awarded in physics in the US has more than doubled and is now at an all-time high (Figure 2) Yet, for much of this period, African American representation among physics bachelor's degree earners stagnated, only recently increasing to reach 1995 levels.

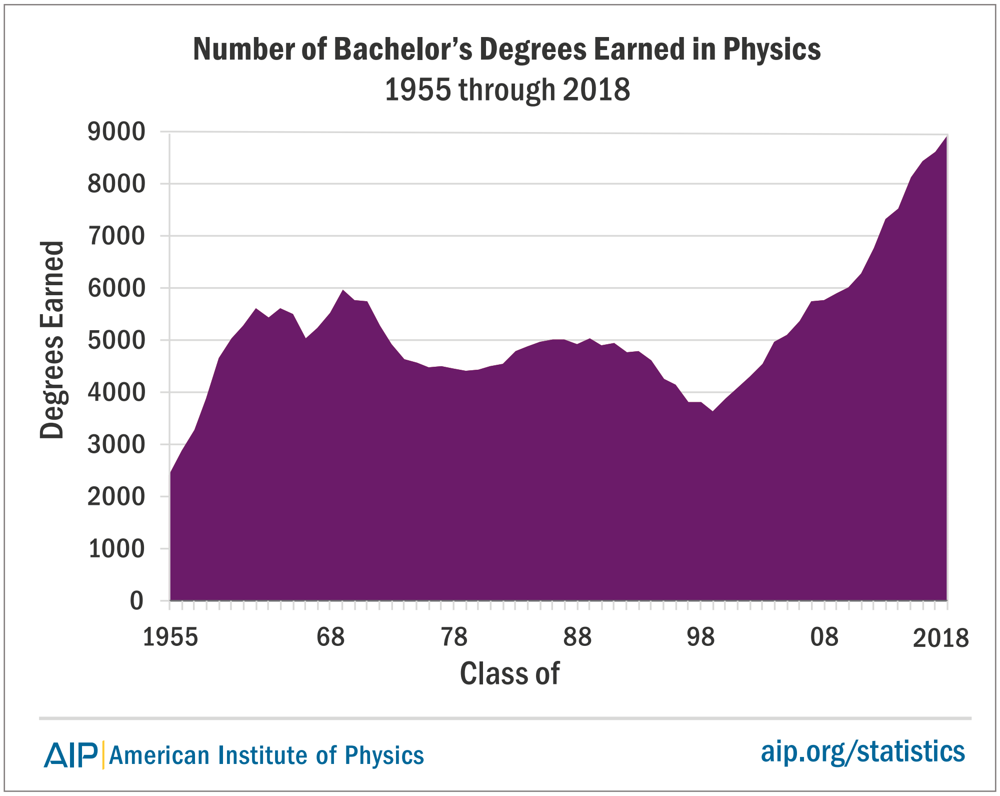


Figure 2: Number of Bachelor's Degrees Earned in Physics 1955 – 2018

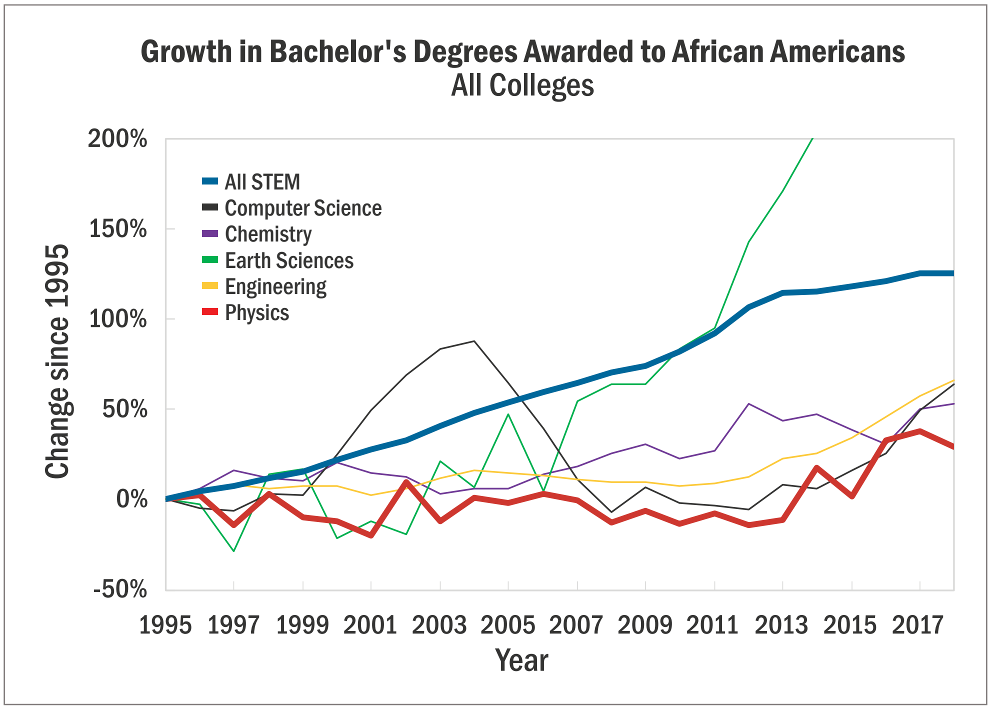


Figure 3: Growth in bachelor's degrees awarded to African Americans All Colleges
Source: IPEDS

Second, during this same period, the percentage of African Americans earning bachelor's degrees in all fields has grown much faster than the overall population (degrees more than doubled between 1995 and 2015, while the population grew by 23%).[6] But physics has not benefited from this growth. From 1995 to 2015, the number of physics bachelor's degrees awarded to African Americans increased by 4% compared with a 36% increase for all physical sciences (Merner and Tyler 2019, and Figure 3). In contrast, the fraction of Latinx students among physics bachelor's degree earners—while still well below the Latinx representation in the US population—has increased significantly in the past 20 years (Figure 4).

From 1995 to 2015, the number of physics bachelor's degrees awarded to African Americans increased by 4% compared with a 36% increase for all physical sciences (Merner and Tyler 2019, and Figure 3).

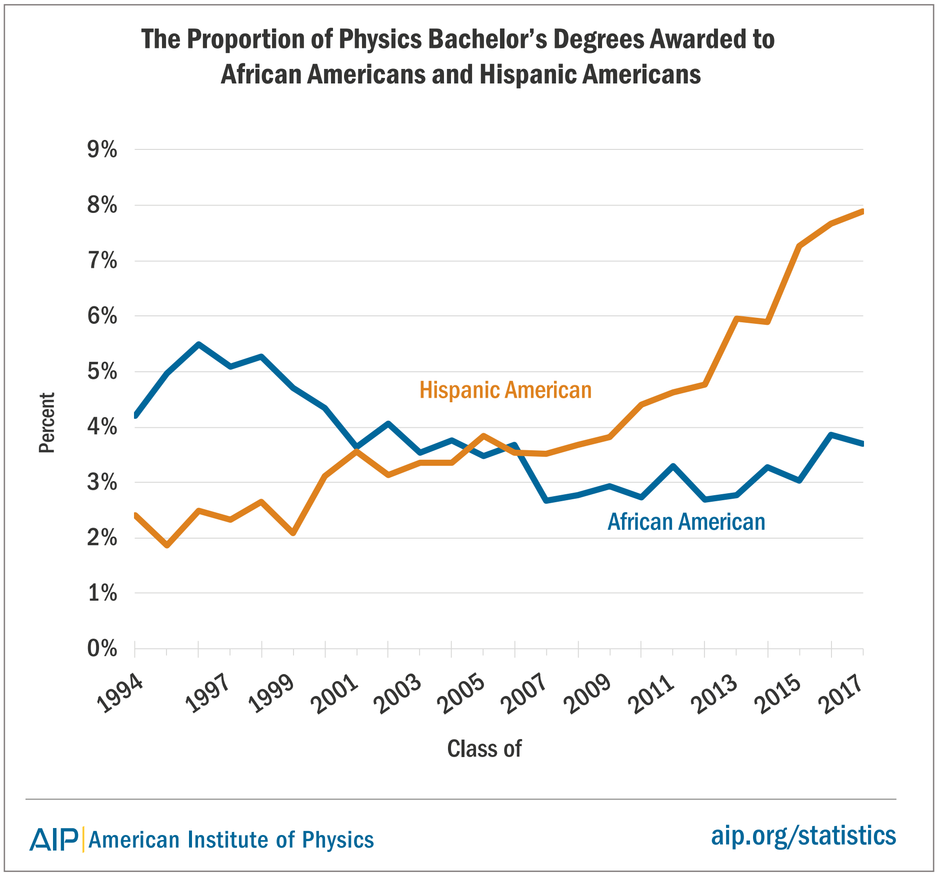


Figure 4: Proportion of Physics Bachelor's Degrees Awarded to African Americans and Hispanic Americans

Another important consideration was that a dearth of African Americans earning bachelor's degrees in physics and astronomy has the ripple effect of reducing the pool of African Americans pursuing graduate study in these fields, entering the academy, and ultimately being in a position to educate and inspire the next generation of students.

6 Data from the National Center for Education Statistics' Digest of Education Statistics.

Finally, while existing reports have examined the underrepresentation of minoritized students, and even Blacks in STEM, there had not been a comprehensive study to understand why the fraction of African Americans earning bachelor's degrees in physics, despite decades of programs and interventions, has remained within the 2–5% range.

TEAM-UP was charged to investigate the persistent underrepresentation of African Americans in physics and astronomy at the bachelor's level and produce a report to AIP Member Societies, US physics and astronomy departments, and other key stakeholders with evidence-based recommendations for increasing the percentage of African American bachelor's degrees in physics and astronomy. LCURM set a long-term goal to increase the percentage of physics degrees awarded to African Americans to match the percentage earned in all fields. On the basis of current numbers, this requires more than tripling the number of physics degrees to African Americans.

This report adopts the goal of at least doubling the number of physics and astronomy bachelor's degrees awarded annually to African Americans from the 2017 values of 238 and 12, respectively, to approximately 500 and 25 by 2030.[7] This will bring gains achieved since 1997 to parity with the growth experienced by African Americans across the physical sciences and engineering (assuming no change in the African American percentage in other fields between 2017 and 2030). Achieving this doubling goal is a necessary step toward equalizing the representation of African Americans in physics and astronomy compared with all other fields. We believe that the institutionalization of the recommendations in this report will lead to even more gains in the future.

This report adopts the goal of at least doubling the number of physics and astronomy bachelor's degrees awarded annually to African Americans by 2030[7].

Although numbers are important, they do not tell the whole story. Given that we know there are talented African American students who could major in physics and astronomy but do not, there must be something else at play. We cannot hope to meet our goal without transforming the norms, values and culture of physics and astronomy. This second goal is at least as important as the doubling goal because it opens the way to improvements in diversity, equity, and inclusion more broadly and because without it, improvements are unlikely to last.

In December 2017, TEAM-UP—comprising a diverse group of 10 physicists, astronomers, and education researchers with differing racial, ethnic, and gender identities, at various stages of their careers, and supported by two AIP staff members—convened and launched its two-year study.[8]

From the beginning, TEAM-UP's research goals were threefold: 1) to understand the experience of current African American undergraduates within physics and astronomy and the factors that lead these students to persist to their bachelor's degree; 2) to learn how the overall landscape of physics and astronomy culture and climate contributes to or diminishes their success; and 3) to uncover what impedes or promotes the culture change necessary for their persistence.

---

7 2017 national data from IPEDS; this acronym and other terms are defined in the Glossary.

8 For TEAM-UP members and profiles, see https://www.aip.org/diversity-initiatives/team-up-task-force/members.

TEAM-UP set out to answer these questions with a strategic, multipronged approach to collecting data that included: 1) a national survey of African American students that was later extended to all physics undergraduate students; 2) a survey of a cross-section of physics departments; 3) African American student interviews conducted at the 2018 National Society of Black Physicists conference; 4) site visits to five physics departments that have been successful in attracting and retaining African American students; and 5) prior relevant research. As a result, the TEAM-UP report, unlike prior reports on related topics in STEM, provides both original research and research-based recommendations.

At the outset, LCURM requested that TEAM-UP also engage groups outside the traditional physical science sphere, including community organizations, secondary schools, and private employers. The task force determined that gathering information so broadly was infeasible for the two-year study period and thus limited its investigations to the undergraduate years. However, there is much still to be learned about the experience of African Americans in high school and their transition to college and the extent to which these factors contribute to their underrepresentation in physics and astronomy.

TEAM-UP also planned originally to perform a site visit to an astronomy department but was unable to schedule one. Still, our survey, interviews, and several site visits include data from astronomy students, and one of our site visits was to a department of physics and astronomy.

This report is the culmination of TEAM-UP's two years of work and presents its findings and recommendations based on these data.

Methodology

TEAM-UP was initially organized into subcommittees focusing on the student survey and interviews, working with departments previously identified as interested partners, site visits, research literature review, and student and public engagement. The student survey and a survey of departmental activities in partner schools were completed first, as the other activities depended on them.

The student survey was designed to assess students' planned behaviors and intentions as well as their experiences in their major. It was developed and carried out by researchers from the AIP Statistical Research Center (SRC), University of Maryland education researchers, AIP project staff, and TEAM-UP members to examine differences across ethnic groups based on the STEM Identity Model of Fries-Britt et al. (2019). Appendix 2 provides a detailed examination of the survey design, references key literature, and presents findings and discussion of key factors. The survey was conducted in the late spring and early summer of 2018 using snowball sampling initially aimed at African American undergraduate physics and astronomy students; it was later opened up to all undergraduate students to provide comparator data. The survey was initially distributed to HBCU physics department chairs for dissemination to their students, Society of Physics Students chapters at HBCUs, AIP Member Societies including the American Physical Society's (APS) National Mentoring Community, Sigma Xi for distribution to appropriate members, the National Society of Black Physicists meeting attendees, and TEAM-UP personal contacts. Once the survey was opened up to all students, we asked those same groups to distribute the survey more broadly. In all, 232 students completed the student survey, and 53% of those respondents were Black or Black biracial students (those who indicated both Black or African

American and at least one additional race or ethnicity). The majority of the students were physics majors (91%). Our initial targeting of professional organizations may have resulted in an atypical group of subjects with higher-than-average levels of commitment to their major.

To augment survey data, interviews were conducted with 25 students attending the 2018 National Society of Black Physicists Conference in Columbus, Ohio. The interview protocol was informed by the findings of the survey to further explore student experiences in their major and department. The interviews sought information on student-faculty interactions and department climate and more generally sought to amplify student voices and experiences. Once interviews were transcribed and checked for accuracy, the research team coded the responses in teams of two. Using a constant comparative method, each transcript was reviewed to identify key themes and findings. The full team made decisions about final data and categories.

The subcommittee on partner departments aimed to learn from physics and astronomy departments that had expressed interest in TEAM-UP about their activities and the culture of their departments broadly. Partner departments fell into four categories: 1) Historically Black Colleges and Universities (HBCUs), 2) Predominantly White Institutions (PWIs) where the percentage of physics bachelor's degrees awarded to African Americans is at least twice the national average (based on a five-year average), 3) PWIs with a smaller percentage of African American physics bachelor's degree recipients than other STEM fields in their institution, and 4) other institutions that do not fall into the previous three categories but were eager to contribute.

TEAM-UP members, project staff, and AIP SRC staff developed an assessment survey that queried departments about the support structures they provide for their students and how their African American students engage with those embedded structures (Appendix 4). The survey was sent to 82 physics departments, and 50% completed the survey. Their responses were analyzed by SRC staff and TEAM-UP members, and the results informed the selection of departments for site visits.

The site visit subcommittee designed a protocol (Appendix 7) and worked with the partner subcommittee to select departments to approach for a one-day visit. The departments selected for site visits were the most successful among their peers in terms of the numbers of African American physics bachelor's degrees awarded during the previous five years. These one-day visits were conducted by teams of three in the fall of 2018 and the spring of 2019. During these visits, the teams conducted interviews with faculty, deans, provosts, other relevant administrators, departmental staff, and students to learn about best practices; the culture of the institutions; and how their values, policies, and practices contribute to student success (Appendix 5).

The institutions visited by TEAM-UP included an HBCU, two Predominantly Black Institutions (PBIs), two PWIs that are doctoral-granting institutions with very high research activity, one PWI whose highest physics degree is a bachelor's degree, and two public comprehensive universities. Due to overlap in these categories, a total of five departments were visited. The coverage across institutional types was somewhat fortuitous because the selection process depended not only on degree production and institutional type, but also on the departmental practices described in the departmental survey and on the availability of the department to host the site visit team. Those departments that adopted many promising practices were not only successful in graduating African Americans, they also were generous in sharing their experiences with our site-visit teams. Summaries of each site visit are provided in Appendix 6.

Though no comprehensive study of African American physics undergraduates had been done before the TEAM-UP study, there does exist a body of knowledge about African Americans in higher education and STEM. TEAM-UP undertook a review of this literature to inform the surveys, site visits, and interviews and to augment task force research. The task force itself includes education researchers and sociologists who have contributed to this literature. Appendix 11 provides a guide to the research literature on African American physics and astronomy undergraduates, organized into factors used throughout this report.

Supporting Student Success

The outcome of the TEAM-UP task force's research—including student interviews, site visits, surveys, and an extensive review of the extant literature—illuminates five key factors affecting the success or failure of African American students in physics and astronomy: (1) Belonging, (2) Physics Identity, (3) Academic Support, (4) Personal Support, and (5) Leadership and Structures. From these key factors we arrive at 20 findings that motivate a set of 25 recommendations directed at individual faculty, physics and astronomy departments, and professional societies. In general, each finding leads to a recommendation, which in most cases matches the practices in exemplary departments. For each factor, a fifth recommendation addresses interactions between departments and other actors such as alumni, university-level services, and professional societies.

Full background and research results, including detailed information about the surveys, site visits, and our literature review, are presented in the appendices. This chapter presents our key findings and recommendations concerning student success, backed by evidence from our research. The findings and recommendations are grouped by each factor. For ease of reading, the first two findings and recommendations are presented for each factor first, followed by the remaining two findings and three recommendations.

FACTOR 1: BELONGING

Fostering a sense of belonging is essential for African American student persistence and success.

A sense of belonging is one of three factors related to students' emotional state that educational psychologists have identified as mediators of learning (Trujillo and Tanner 2014).[9] It is defined as a feeling of being part of

9 The other two factors are self-efficacy (beliefs about one's ability to do something) and science identity (how one sees oneself with respect to science). We do not include self-efficacy as one of our major themes because it did not emerge as one of the largest factors in our research across race, although it has a strong dependence on gender (e.g., Nissen and Shemwell 2016). See Appendix 2 for a discussion.

a community. This sense of belonging (also called belongingness) is critical for student success. Students consistently identify it as a key factor in their own persistence.[10]

When thinking about belonging, many physicists and astronomers first imagine the harmful effects of its opposite, exclusion. For example, “You’re only here because of your race,” is a hurtful and inaccurate assertion that many African American students have heard repeatedly, and many physicists condemn it.[11] By focusing on the negative implications of belongingness, however, we can fail to recognize the substantial benefits of fostering a strong positive sense of belonging in students.

In our surveys, interviews, site visits, and the research literature we found a strong connection between inclusive behavior by faculty and peers, a sense of belonging, and student persistence. Students who have positive experiences in their department tend to have a stronger sense of belonging to the physics and astronomy community and are more likely to persist. Focus group interviews, site visits, and open-ended questions on our student survey provided important opportunities to learn about students’ experiences and how those contribute to or detract from a sense of belonging. Students who expressed a sense of belonging reported interactions with faculty and staff that are affirming. They cited the value of interacting with faculty, staff, and peers who know them personally, invite them to events, and encourage their participation in department activities. Conversely, students who reported interactions with faculty, staff, and/or peers that were discouraging, unwelcoming, and toxic had a strong sense they do not belong in the department.

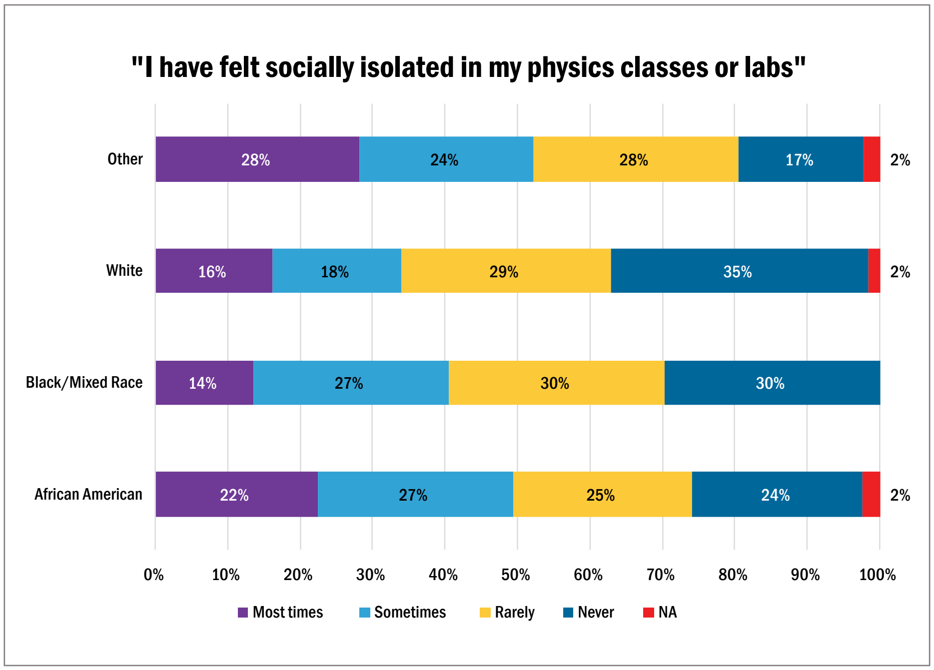


Figure 5: Students’ sense of isolation in physics classes or labs by race
Source: TEAM-UP student survey Caption: Students’ sense of isolation in physics classes or labs by race.

10 The themes raised most often by African American students in our surveys and focus group interviews were: finances, sense of belonging, and faculty interactions (Appendix 2).

11 The physics community reacted strongly to an implicit reference to belonging in a physics classroom made by US Supreme Court Chief Justice John Roberts in 2015. Roberts asked, “What unique perspective does a minority student bring to a physics class?” See http://eblur.github.io/scotus/.

Key Findings

1a. Faculty interactions have a powerful effect on student retention in, or departure from, the major. Students' sense of belonging increases with the number of faculty who get to know them as individuals and demonstrate support for their success.

1b. Peer interactions are also very important, especially in mitigating or exacerbating imposter phenomenon and stereotype threat. When student clubs and organizations like the Society of Physics Students are inclusive and supportive of all students, they can provide valuable peer support.

One question on our student survey asked, "What has helped you to succeed in your undergraduate career?" The most frequent responses were supportive interactions with faculty and peers. The most effective faculty engage students fully as individuals and provide demonstrable encouragement, as noted by one of our interviewees:

> "I had to take a break from doing research for a while with the professor that I had been doing research with just because I was like, 'I want to be able to put [in] my full effort, but I don't know if I can at the moment.' Then he was still inviting me to conferences, inviting me to telecons and that kind of thing. He was still trying to keep me included and asking how everything was going and if I needed anything. I just appreciated that ongoing support even though I couldn't be there the full amount of time."

Our site visits also showed that the positive impact on students increases with the *number* (and influence) of faculty who show such caring behaviors. There were significant differences in students' morale, sense of belonging, and enthusiasm about completing a physics degree between departments in which most or all faculty engaged in consistent, supportive behavior, compared to departments with lone champions.

Peers also have a strong impact on African American students' sense of belonging. For example, high-ability students from underrepresented groups are particularly vulnerable to experiencing imposter phenomenon and stereotype threat, which can affect cognitive performance (Steele 2011), and the African American students in our study were impacted by them as well. (See Appendix 2 for discussions of these topics in our student research.) We learned that African American students' peer-to-peer interactions can either mitigate or increase their effects. One student described the benefit of positive peer interactions:

> "The students are all very helpful. Like upperclassmen . . . if you have questions about, I don't know, modern or classical or something, everyone's pretty open to helping because we all want each other to succeed."

Another described the impact of negative peer interactions:

> "[T]here [were] certain times in class when the professor would pose a question and I would have the answer. Then another student in the class who was present and happened to be a White male [would be] like, 'No, that's not right.' So I didn't propose my answer to the class. I was embarrassed because I was like, 'I'm just going to get it wrong' but ended up being right. Just things like that where your colleagues or other students around you just make me feel more doubtful. I'm trying to work around that and still have confidence despite their opinions."

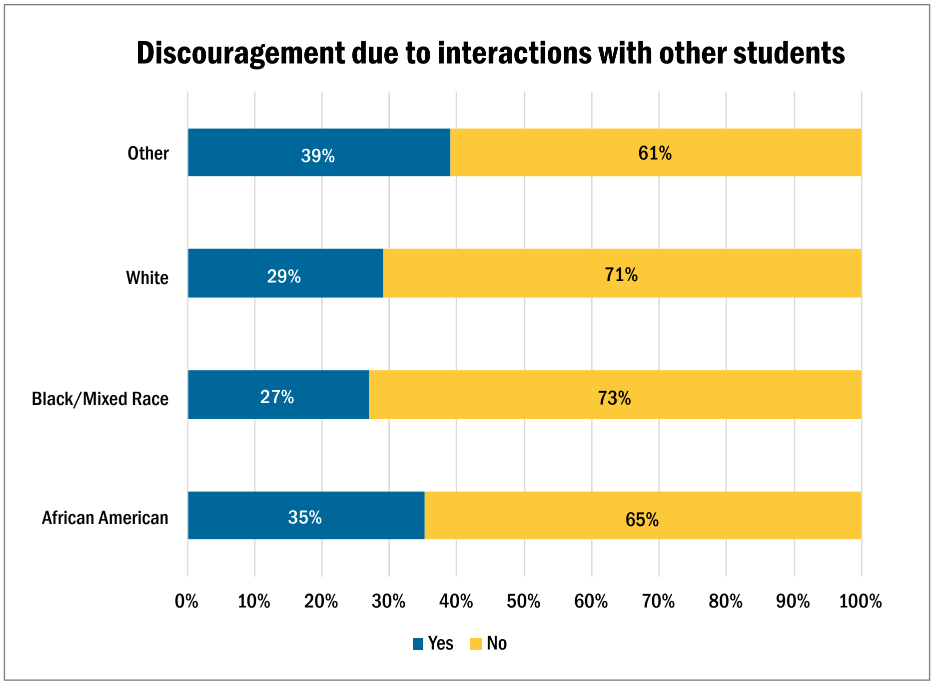


Figure 6: Student sense of discouragement due to peer interactions by race
Source: TEAM-UP student survey

One student noted the impact of stereotype threat on a sense of belonging, describing a

> "constant feeling that I am a representative; therefore I must be flawless [and] not seeing people like me in professors or even grad positions, not really having a confidant within the department . . . feeling incapable of doing the work and feeling less than."

Creating environments that promote positive peer interactions is crucial in fostering a sense of belonging. All of our site visits had active student clubs in which African American students felt included. In the departments with the strongest sense of belonging, students emulated inclusive behavior of faculty to create a collegial atmosphere in which all students felt that they belonged.

These findings lead directly to recommendations to help faculty and students strengthen their capacity for supporting inclusion and belonging. Importantly, these recommendations are followed within the best-performing departments for African American students that we visited.

Recommendations

1a. With the encouragement and support of their chairs, faculty should learn, practice, and improve skills that foster student belonging in their interactions with African American undergraduates.

1b. In classrooms, student clubs, and common spaces, departments should establish clear rules of engagement that ensure that everyone is welcomed and valued and convey that inappropriate behavior will not be tolerated. Departments should also provide spaces and opportunities for education and ongoing discussion among faculty and students on ways to actively foster a sense of belonging and reduce barriers to inclusion.

These recommendations recognize the influence and power that faculty and departments have regarding student experience and success. There is a tension in many departments concerning the relative importance of research and education. Developing the habit of seeking student perspectives, showing interest in and concern for events and topics relevant to their culture, and providing encouragement to those who may not feel they belong requires minimal financing, yet offers substantial benefits in terms of improved student outcomes. Actors with social power must demonstrate inclusive actions in order to increase students' sense of belonging. Departments can exemplify this by providing spaces and opportunities for education and ongoing discussion on how to actively foster a sense of belonging and engagement among faculty and students to reduce microaggressions that invoke imposter phenomenon, stereotype threat, and other barriers to inclusion and belonging. Many universities have centers for teaching and learning that can help faculty build these skills for themselves and as advisers to student groups.

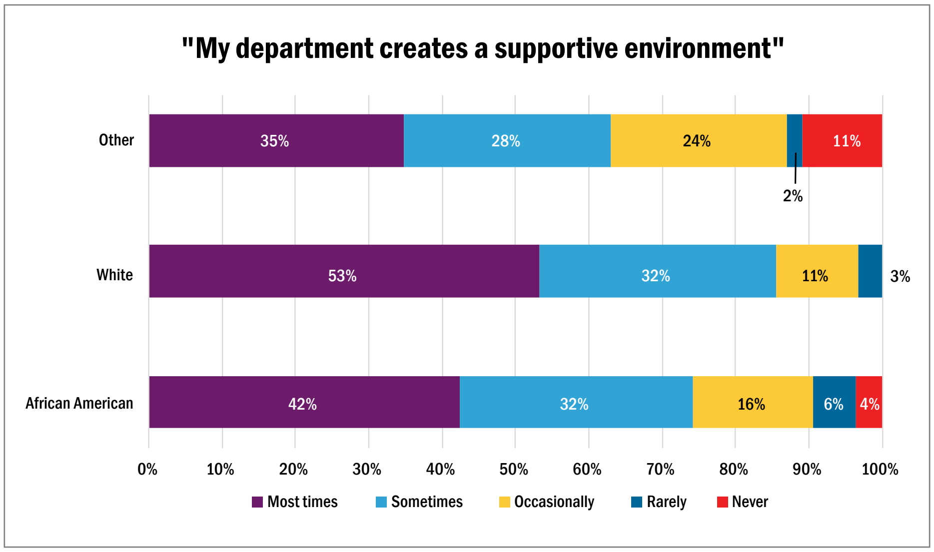


Figure 7: Student perception of physics departmental environment by race
Source: TEAM-UP student survey

Other Key Findings

1c. Peers of the same race/ethnicity/gender provide valuable social and academic support, often through counterspaces (e.g., family, churches, Black student organizations) serving as refuges from departmental cultures that are not highly supportive of African American students.

1d. Microaggressions and discrimination received from their peers diminish students' self-efficacy and persistence.

More than any other group, African American students responding to our survey emphasized the importance of a strong sense of community with peers of the same ethnic group (Figure 8). This is supported by qualitative data illustrating that having peers of the same ethnic group in their major makes a significant difference in the support students feel as they navigate the major. Having peers that they can relate to, study with, and interact with is an important contributor to their success and sense of belonging to the program and department. Students noted the importance of learning from more senior students and their journey in physics. They wanted a strong support network of peers and advisers who looked like them and would advocate on their behalf. Students also intentionally sought out peers outside of the physics major. Essentially, building a community within the same ethnic group is important to overall success and provides a critical mass of peers whom students can relate to without feeling they have to prove that they belong in the program.

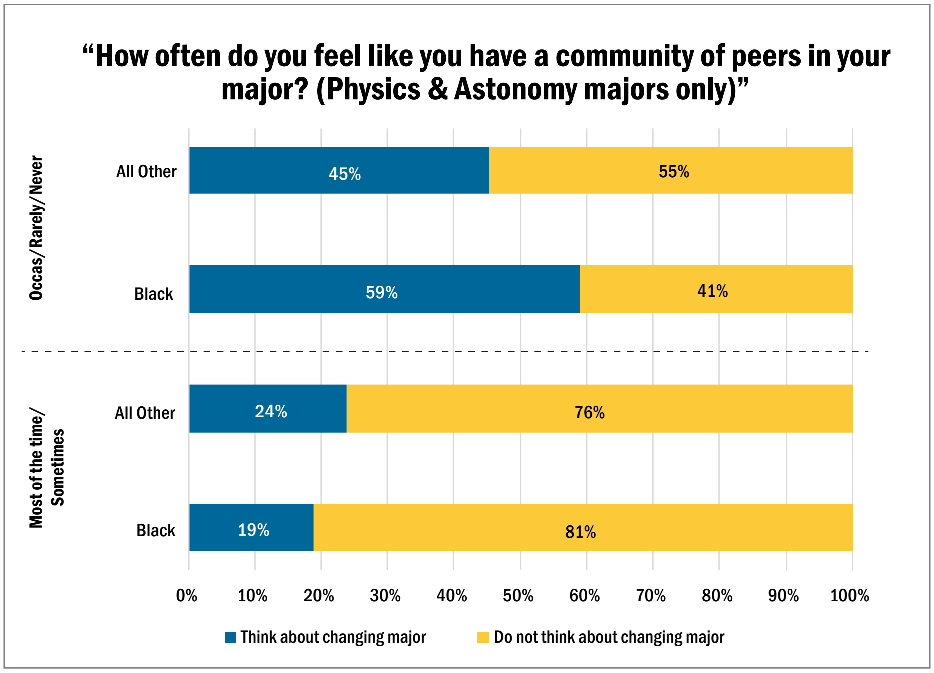


Figure 8: Students' sense of community with peers by race and their thoughts on changing their physics or astronomy major.
Source: TEAM-UP Student Survey Responses

African American students at Predominantly White Institutions often feel a sense of isolation. When asked to identify the greatest barriers to success, one student commented,

> "Feeling isolated in my department and my field and knowing that as I got further in my education, less and less people of color would be there."

Regular exposure to unsupportive peers and faculty who make discriminatory comments, intentionally or unintentionally, will likely derail a student's success in the field (e.g., Rainey et al. 2018) and this is more likely for minoritized students in STEM compared with other fields (Riegle-Crumb, King, and Irizarry 2019). The ability to connect with peers of the same race and ethnicity and other social identities including gender, gender identity, sexual orientation, and disability status, is important for students of any group, but especially for African American students. Often, groups or settings such as the annual NSBP meeting, where minoritized individuals with common social identities can gather, are experienced as counterspaces, that is, safe spaces where students can feel completely supported in the face of prejudice and discrimination (Ong, Smith, and Ko 2017). This virtually ubiquitous discrimination is present in most of our departments whether faculty recognize it or not. For example, a survey respondent noted,

> "The climate of the physics department is very non-inclusive of people of color… They would say [things] like 'You should change your major.' "

This is an example of a microaggression, a slight or insult that communicates a negative message to a member of a marginalized group. Repeated microaggressions can cause serious harm (Sue 2010). Fewer than half of the African American students in our samples reported these experiences (though they did so more often than members of other racial and ethnic groups), but for those who did, they had an impact on their sense of belonging and their perception of their ability to succeed in the major. Often these experiences occurred *in the classroom,* where students felt that their academic abilities were questioned and that they were not included in study groups or assignment groups for class projects. One student shared these examples of microaggressions:

> **"Having people tell me I am wasting my time. Being removed from programs and labs for working off campus. Not having support from faculty on campus, and [faculty] telling me they will not write letters of rec[ommendation]."**

These interactions, feelings, and concerns are real for students and will have an impact on their persistence because they undermine belonging and STEM identity (discussed below). Supporting the existence of counterspaces, and taking proactive steps to identify and eliminate prejudice and discrimination, are two important ways that departments can help minoritized students respond to isolation and microaggressions (Johnson et al. 2017).

Other Recommendations

1c. Faculty who teach or advise undergraduates should become aware that counterspaces are important for African American students and should assist students in finding the support they need inside and outside the department.

1d. Departments should establish and consistently communicate norms and values of respect and inclusion. They should periodically assess departmental climate with help from outside experts and should respond, as needed, with educational workshops led by experts from student affairs or other resources.

1e. Professional societies should lead a coalition, similar to the Societies Consortium on Sexual Harassment in STEMM, to address identity-based harassment beyond sexual harassment.[12] Alternatively, members participating in the Societies Consortium should urge the existing body to broaden its efforts to include all forms of identity-based harassment including microaggressions and acts motivated by racism and bias.

Recommendations 1c and 1d are supported by examples from our site visits and the research literature as described in the corresponding findings above. The organizers of the National Society of Black Physicists recognized the need for counterspaces in founding the organization in 1977, and indeed, when we interviewed students at the NSBP conference in 2018 as part of this report, they recognized the significance of NSBP as an integral counterspace for them. Encouraging African American students to attend NSBP and other scientific conferences that center the identities of African American students, and providing travel funding, is an example of how to activate Recommendation 1c. Other examples are given by Johnson et al. (2017).

Department climate is another area in which faculty have agency over students' experiences. One action that departments can take is to assess that climate. Given complex issues of student confidentiality, feelings of safety, and trust, it is important that departments not rely on their own climate assessments but engage outside experts. Students may fear retaliation if they report negative experiences to their own department. External experts not only assess but can also offer solutions to ameliorate damaging and toxic practices. For almost three decades, the APS has offered a Climate Site Visit program to assess departmental environments with a view to gender, race, and ethnicity. Most colleges and universities have experts in student affairs, multicultural offices, or offices of diversity, equity, and inclusion that can help address issues of unwelcoming environments for students.

---

12 For more about the Societies Consortium, see http://educationcounsel.com/societiesconsortium/.

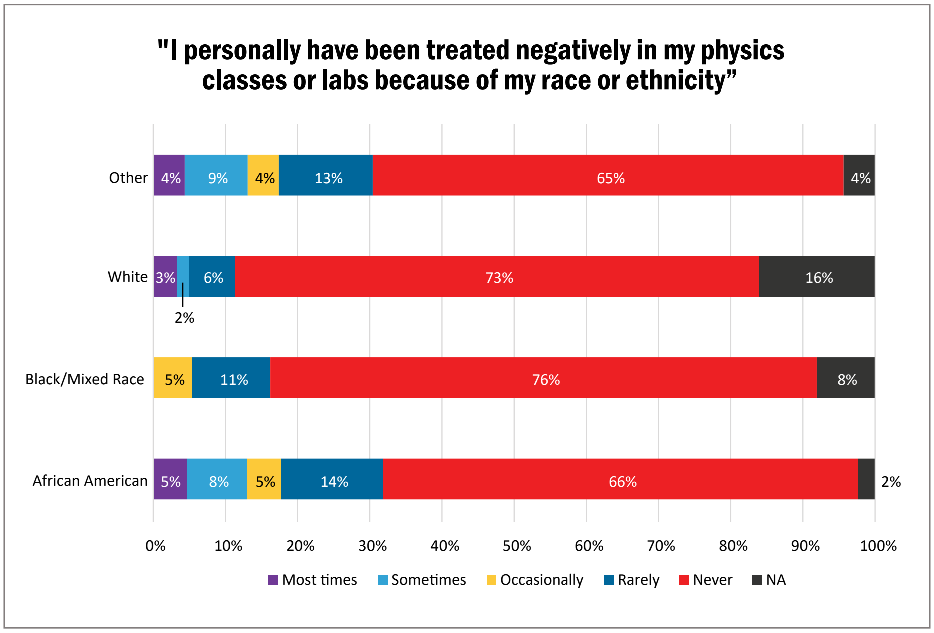


Figure 9: Student experiences of negative treatment due to race or ethnicity
Source: TEAM-UP Student Survey

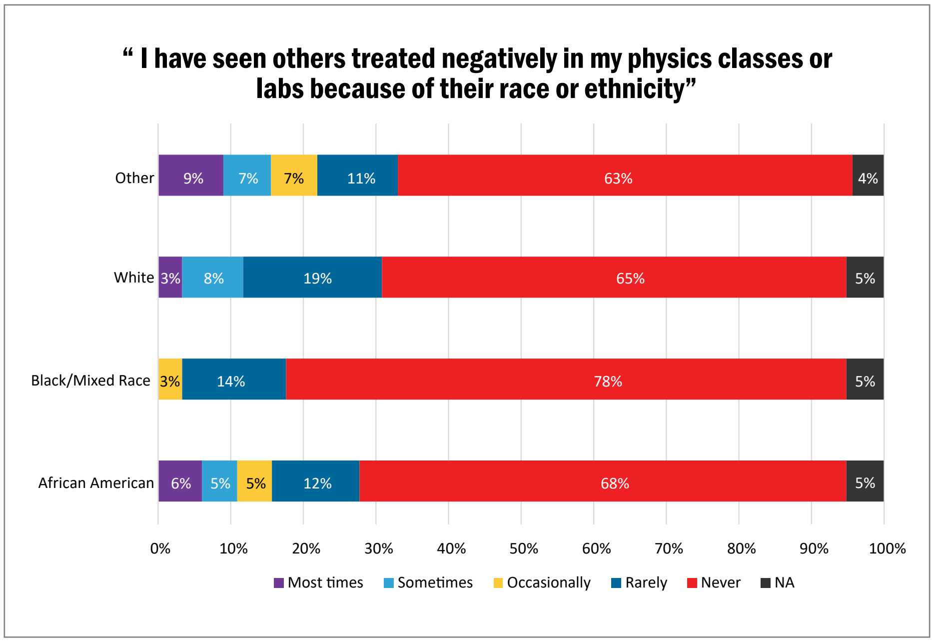


Figure 10: Student observations of others being treated negatively due to race or ethnicity
Source: TEAM-UP Student Survey

Recommendation 1e, made to physics and astronomy disciplinary societies, recognizes that sometimes the insults experienced by department members are not small, and that they can involve intersecting social identities. The recent National Academies report on sexual harassment in academic science, engineering, and medicine (NASEM 2018a) highlighted the imperative of addressing multiple forms of harassment, including gender-based harassment whose most subtle and widespread form is gender-based microaggressions. However, discrimination and harassment have multiple forms and targets. As Kimberlé Crenshaw noted when coining the term *intersectionality* as part of a legal argument, discrimination that occurs as the result of overlapping systems of oppression, like the racialized gender discrimination African American women face, cannot be understood on the basis of gender alone, or race alone, but must be interpreted as an intersecting set of oppressions (Crenshaw 1989). Moreover, harassment on the basis of sexual orientation is directly harmful to many physicists (Atherton et al. 2016). The task force urges the professional societies to broaden their approach so as to address all forms of identity-based harassment in academia, and to focus greater attention on intersections of oppression as experienced by such groups as LGBT people of color and women of color (Clancy et al. 2017).

FACTOR 2: PHYSICS IDENTITY

To persist, African American students must perceive themselves, and be perceived by others, as future physicists and astronomers.

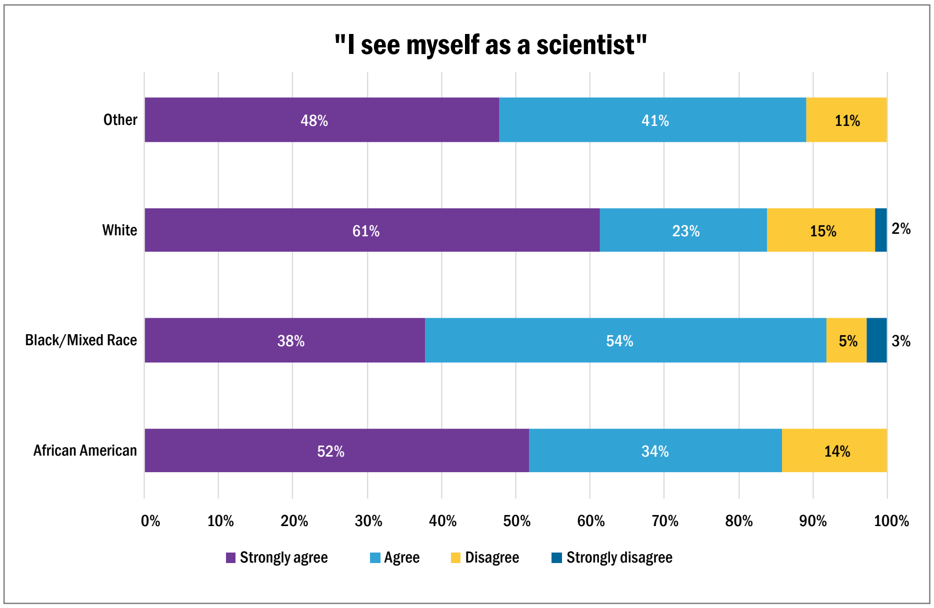


Figure 11: Students' perception of self as a scientist by race. White students more strongly perceive themselves as scientists than all others.
Source: TEAM-UP Student Survey

Physics identity has been defined as how students perceive themselves with respect to physics.[13] This evolves with their perceptions and navigation of experiences with physics including how others recognize them (Carlone and Johnson 2007; Hazari, Sadler, and Sonnert 2013). A positive physics identity—i.e., a feeling that "I am a physicist" or "I see myself becoming one"—is a significant predictor of persistence and outcomes (Aschbacher, Li, and Roth 2010). Students of color, especially women, must navigate a professional culture

13 Any other scientific discipline can be substituted for physics throughout this section. See also footnote 2.

that is White, masculine, and heteronormative as part of their physics identity development (Monsalve et al. 2016; Hyater-Adams et al. 2018). These students have to overcome entrenched stereotypes about who can be a physicist. Thus, who becomes a physicist depends not only on their own self-perception but on complex and ubiquitous social and emotional factors that extend beyond the attainment of physics or astronomy subject matter expertise. Many physicists assume that an early interest in physics, combined with determination, hard work, and some luck, provides the necessary and sufficient conditions to become a physicist, but this is not supported by research. Such an assumption renders invisible the very real cultural and social impacts that African American students feel and must navigate while also acquiring expertise in their chosen subject (Hyater-Adams et al. 2019).

In addition to the research literature, our surveys, interviews, and site visits all indicated the significance of physics identity development. While a sense of belonging is essential for African American student success, a student can feel a sense of belonging and still not identify as a physicist, especially if the concept of "physicist" is incongruent with their social identity. Our research and the existing research literature identify several steps that faculty can take to aid the development of a student's physics identity.

Key Findings

2a. Faculty encouragement and recognition are key enablers of physics identity for African American students. Physics identity development increases with the number of faculty who encourage and recognize student success.

2b. Participation in research, attendance and presentation at conferences, and working as a Learning Assistant all foster physics identity development.

The first finding is supported by the research literature (Wang and Hazari 2018), our interviews, and our site visits. At the highest-performing departments we visited—marked by the persistence, morale, and success of their students—the African American students expressed great appreciation for the fact that faculty had high standards for and expectations of them and prepared them appropriately to meet those expectations. Faculty encouragement was especially helpful for the students. These faculty expressed pride about their students in conversations with the site visit committee. It should be noted that not all faculty encouragement and recognition of student performance is inherently positive. When students are "encouraged" to leave the field, or when faculty "recognize" a student's efforts as being of limited or no use, it produces a strong negative effect on them. As one African American student noted in an interview,

> **"I've had two professors ask me why I'm in physics. They see how much I'm struggling. Like, 'Why are you still a physics major? Why do you want to do this?' Multiple times. It's like, 'Well, I'm here because this is what I want to do.' They're like, 'You're making your life difficult doing all this.' It's very discouraging when you hear [this]."**

Finding 2b, on the importance of students practicing the role of physicist as researcher and educator, is widely recognized in the physics community and is, indeed, the foundation of the apprenticeship model of graduate education (NASEM 2018b). Undergraduate research was emphasized in all of the departments we visited.

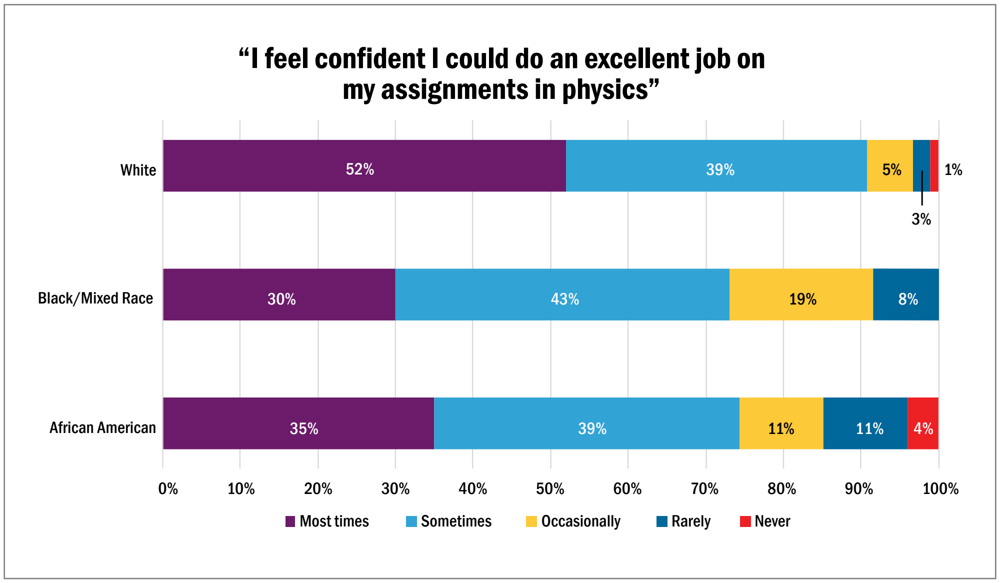


Figure 12: Student confidence on assignments in physics by race
Source: TEAM-UP Student Survey

At one of our site visits, the faculty noted that Learning Assistants helped the faculty develop lesson plans and recommended giving the students more power in the classroom. Research has demonstrated that participation as a Learning Assistant fosters physics identity development (Close, Conn, and Close 2016). The combination of research, conference participation, and participation as a Learning Assistant is notable at Chicago State University in the success of its ChiSci Scholars program (Sabella et al. 2017).

Recommendations

2a. Departments should invite speakers with demonstrated research expertise on physics identity development and should work with faculty on evidence-based ways to strengthen students' sense of physics identity, including encouragement and recognition.

2b. Departments should examine whether their current activities foster physics identity, assess their efficacy across race/ethnicity/gender and other social identities, and modify such activities as necessary.

The most promising strategies we have identified for fostering physics identity development and student success are faculty intensive and are contrary to the normative practices of physics in research universities that value autonomy and individual effort. For faculty or departments to change their practices, they must critically examine their assumptions, understand the nature and benefits of change, and feel empowered to make the changes.[14] A key first step is to learn from experts in physics education research whose efforts have made an impact in departments similar to one's own. Faculty can develop an evidence-based evaluation mechanism to compare the intentions and outcomes of their physics majors; to disaggregate these by race, ethnicity, and gender; to explore within their own department the causes of systematic differences that arise; and to correlate the results with their department's self-image and values. Such critical self-reflection can help improve the success of African American students.

14 The next chapter discusses mechanisms for change in greater depth.

One simple way departments can enhance a student's physics or astronomy identity is to provide funding for student research, conference attendance, travel to a summer research internship, or travel to a job interview. This is especially important for students who face financial hardship.

Other Key Findings

2c. Faculty of the same race and ethnicity provide helpful role models whose support is especially meaningful to African American students.

2d. The connection of physics to activities that improve society or benefit one's community is especially important to African American students.

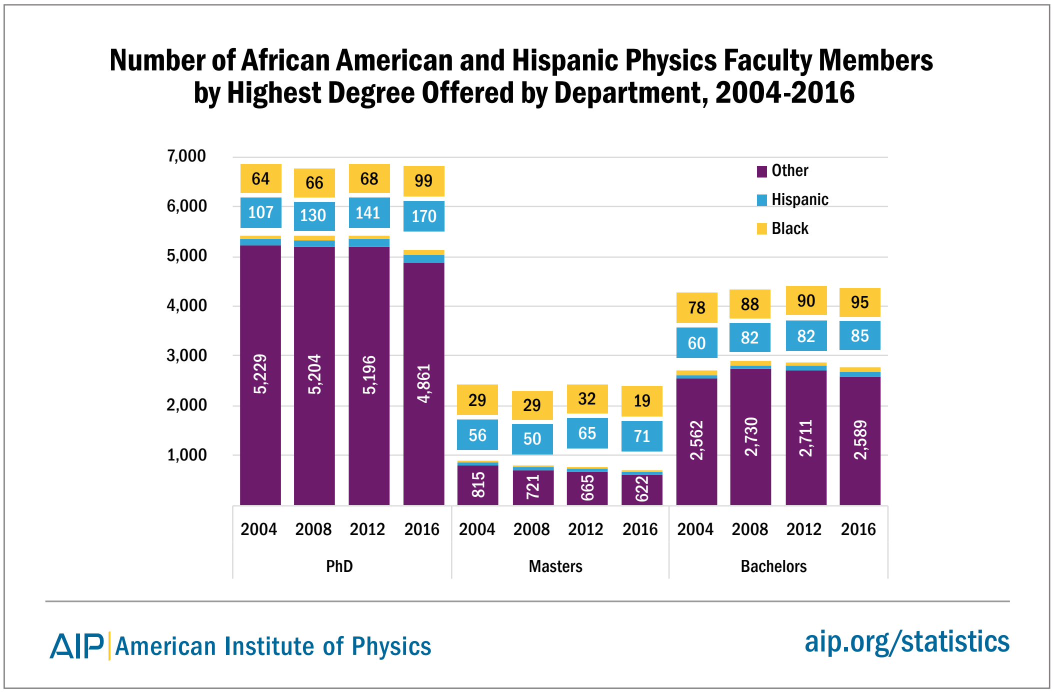


Figure 13: Physics Faculty by race and highest degree offered

Research shows the importance of having role models of the same race and ethnicity in supporting African American student belonging, identity, and persistence (Johnson et al. 2019). Students we interviewed at the NSBP conference addressed this point directly. For instance, one said:

> "I haven't had a Black STEM professor yet. That's one thing that I envy [about] people that go to HBCUs, that they have that type of connection. Yesterday I was looking at the faculty and staff of my physics department and I didn't see any Black faculty on it. It's not necessarily discouraging, but it's like, 'Okay, I guess.' [You've] got to push through; but coming here to this conference, it honestly makes me happy to see this many Black people in physics and Black people in astronomy."

In our site visits, African American students praised faculty who were highly supportive independent of their social identity, yet we observed an overall higher level of student belonging and physics identity development in departments whose faculty were majority Black, compared with those having one Black faculty member or none at all.

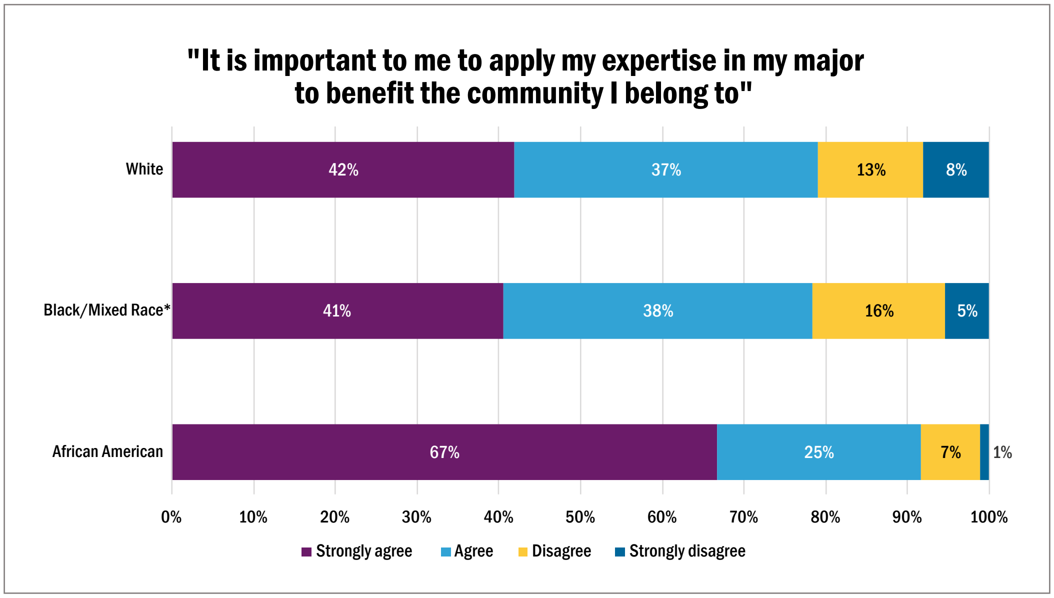


Figure 14: Students' motivation to benefit their community by race
Source: TEAM-UP Student Survey

Our survey, interviews, and site visits all affirmed that African American students have a strong commitment to giving back and helping others (Figure 14). These findings are consistent with research on identity-based motivation theory (Oyserman 2015), which suggests that individuals are driven to act in a manner that is congruent with their sense of belonging to a particular group with whom they share values and behaviors. In our analysis, African American students showed a high level of commitment to their own ethnic and religious communities. This strong commitment to prosocial behavior is reflected in students' desire to mentor others as well as conduct research on issues impacting the African American community.

Other Recommendations

2c. Departments should diversify their faculty with respect to race/ethnicity/gender and other social identities in such a way that support of underrepresented students is provided by multiple faculty of varying identities.

2d. Departments should communicate the ways in which a physics degree empowers graduates to improve society and benefit their communities, for example by inviting alumni to speak to students about these issues.

2e. Faculty should feature and discuss a broad range of career options with undergraduates, utilizing resources such as the AIP/SPS Careers Toolbox and the advice of African American alumni.

Faculty of color aid in the retention of African American students by contributing to their physics and astronomy identity formation and sense of belonging. In particular, faculty of color help students form a sense of belonging by allowing students to place themselves farther along their desired track (alignment), fit into a community of practice (engagement), and create shared histories (imagination). The development of these modes of belonging aid in identity formation (Wenger 1998).

Furthermore, the presence of more faculty of color in physics and astronomy helps to actively disrupt the dominant scientific culture that is White, masculine, and heteronormative (Brickhouse 2000). As stated above, when African American students are constantly exposed to microaggressions, racist stereotypes, and other sentiments that suggest they don't belong because of their identity or identities, having faculty of color in close proximity disproves the notion that who they are makes them incapable. Taken together, a positive feedback loop emerges: a vibrant community of faculty of color in physics and astronomy departments helps to retain and produce a vibrant community of students of color by building the attributes that we identify as key to African American success in physics. We note that faculty of all demographics should contribute to mentoring and student success, but the data suggest that in institutions where African American students are a minoritized population and/or do not receive the encouragement they need to thrive, they often feel more comfortable with someone of the same race/ethnicity/gender. An equitable division of labor generally requires more than one faculty member of color in a department. Moreover, all students benefit from learning from faculty of color.

It is important for physics faculty to understand that African American students' commitment to helping their communities affects their career choices. Faculty should validate these choices. Helping students identify the best time in their career progression to be more engaged in helping others will be important for their overall success. Too often, when they express these prosocial interests, students are dismissed outright as lacking commitment to the major or are perceived as less capable and not worthy of faculty time and investment. Rather than diminish their vision of how they want to give back to the community, departments must learn to augment and expand what it means to study physics for African American students. In the most effective departments we saw this done in multiple ways, including by inviting alumni of color back to speak with students and by frequent reference to the AIP Careers Toolbox (Appendix 10).

FACTOR 3: ACADEMIC SUPPORT

Effective teaching and a strengths-based approach to academic support are necessary for African American student retention and success.

Academic support is an obvious factor in student success. Too often, however, it is approached from the student deficit model—the idea that minoritized students have, as a consequence of their identity, learning challenges making them less capable than others. Combining deficit thinking with the problematic notion of meritocracy (McNamee 2018)—the idea that success is determined by ability, talent, and hard work—can lead to faulty judgment of students' potential. Site visits to the departments graduating the most African American students, as well as extensive research literature, show that the more effective approach recognizes student capabilities and builds on their strengths. Our survey, interviews, and site visits identified the following elements of academic support most helpful for African American students in physics and astronomy.

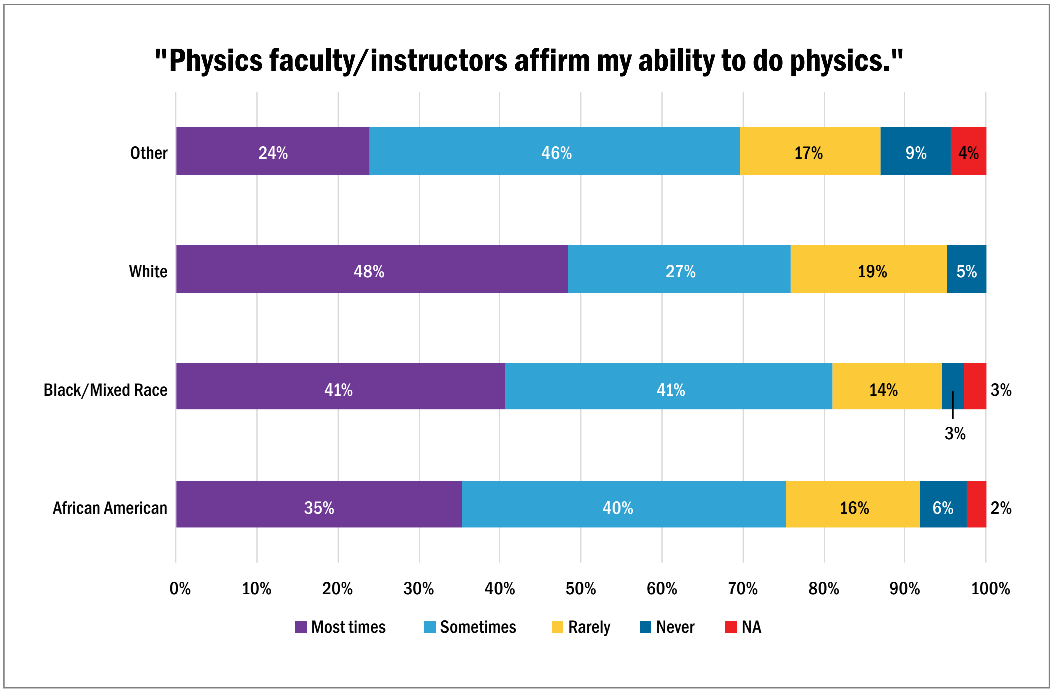


Figure 15: Frequency of physics faculty affirming students' ability to do physics by student race
Source: TEAM-UP Student Survey

Key Findings

3a. Faculty who teach well and demonstrate commitment to students by affirming their academic abilities, encouraging their success, and helping them find additional resources are critically important in fostering student success.

3b. Overall student success increases with the number of committed and caring faculty in a department. It is important for faculty who are not members of marginalized groups to be engaged in these efforts to show students that they are valued.

Our survey, interviews, site visits, and a vast literature (e.g., Kezar and Maxey 2014; Packard 2016; NASEM 2019) all show that interactions and connections with faculty contribute significantly to student success. Professors who demonstrate a high level of commitment to students and are invested in their learning are essential. Those who affirm students' academic abilities, encourage their success, and help them network to find resources are invaluable. These professors were seen as game changers, as reflected in the comments of a student who noted,

> "There was one teacher that—really, honestly, I was going to give up on physics and she changed everything. I mean, she was so passionate about teaching, she knew a lot about physics education and research… She just kept checking in on me, and she would make comments on my test like 'This is not so good. Come see me.' Then she would email me like, "Did you see my comment? Come see me."

The importance of encouragement and academic support by faculty was clear in every one of our site visits. The compounding effect of having multiple faculty committed to caring and devoted to their students was also clear, and in the departments where it was strongest, African American students had the highest sense of belonging and physics identity. We were particularly impressed by the statements made by a large, demographically diverse group of faculty in one physics department:

"You have to set high expectations of students, be realistic about where they are, then take them [to] where they can be."

"These are the most talented students anyone could want."

"I teach because I like learning about people."

"Building community takes a lot of sweat equity."

"When you know someone, you look out for them."

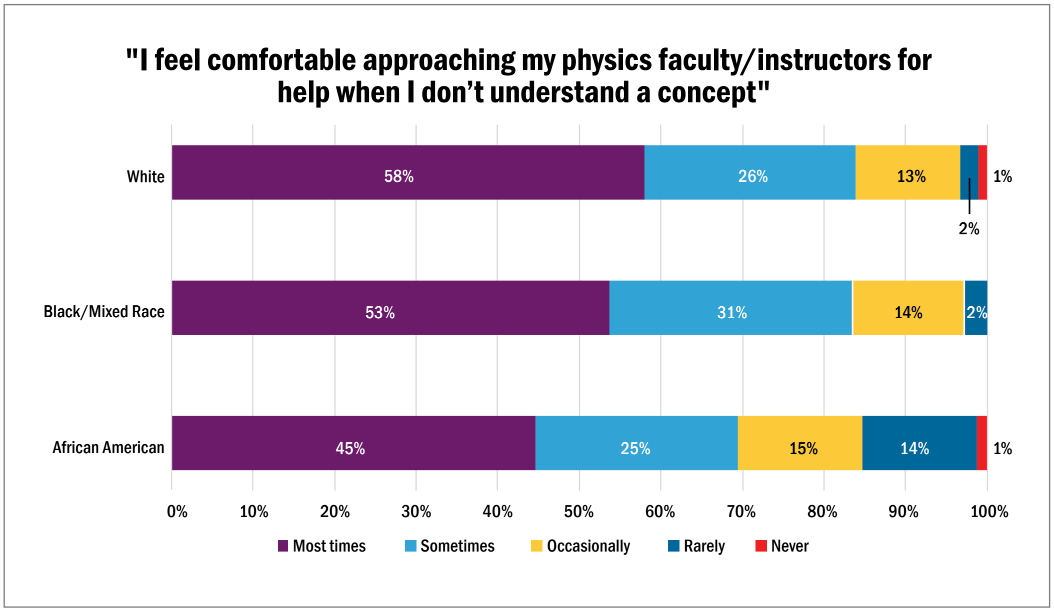


Figure 16: Student comfortability approaching physics faculty for help
Source: TEAM-UP Student Survey

The fact that multiple faculty were dedicated to their success created an exceptionally high sense of belonging and strong physics identity for the African American students at this university, who persisted and graduated at higher rates than in other STEM departments at the school.

Recommendations

3a. Departments should encourage and support all new faculty to attend workshops on teaching and mentoring offered by their campus center for teaching and learning or other venues such as the New Faculty Workshop hosted by the American Association of Physics Teachers (AAPT) in conjunction with the American Astronomical Society (AAS) and APS.

3b. Departments should adopt policies and practices that encourage multiple faculty, including those who are not members of marginalized groups, to engage in formal and informal mentoring of students, and they should recognize and reward these efforts.

Individual departments and their leaders play a key role in defining what success looks like. In order to improve the success of African American students, departments should invest in good educational practices by encouraging new faculty to attend workshops on teaching and mentoring. New faculty members are generally interested in learning and improving skills that will help them succeed. These types of investments at a research university sometimes feel contrary to the norms and values of the profession. However, current and former department chairs across a range of institutional types have found that helping faculty to develop good teaching and mentoring skills helps them to be more effective in both research and education. The recent National Academies report on mentorship (NASEM 2019) provides a rich source of information on theory, practice, and training for mentoring.

Earlier we noted the extra burden that is often placed on faculty of color to mentor students of color. Contributions to all aspects of departmental service should be recognized, including those that may not be formally assigned when unanticipated needs arise in a department. Ideally, the informal advising of students of color would be shared by multiple faculty members. Engaging department stakeholders from non-marginalized groups in this work, provided they do it well, signals its importance to the students. Department chairs and deans should record and reward all service contributions including mentoring students of color. Department chairs can reduce other service burdens, or provide teaching releases, to faculty who are heavily engaged in supporting students.

Other Key Findings

3c. Advising systems that provide early warning of academic, financial, or other difficulties, and that intervene to reach students who may not seek help, are crucial for students to overcome challenges. These services may be provided by professional advisers collaborating with departments.

3d. Having multiple pathways into and through the major helps to recruit and retain students who may not have initially considered physics or astronomy as an option.

> **Our site visits showed that many African American students did not enter college intending to major in physics but were drawn to the department by inspiring classes or by peers who invited them to club events.**

Georgia State University has eliminated achievement gaps through innovative and exemplary advising practices. Since 2015, Georgia State has been the only national university at which Black, Hispanic, first-generation, and low-income students graduate at rates at or above the rate of the student body overall.[15] These groups' broad success is due to intrusive advising systems that use predictive analytics based on student data and years of

15 https://success.gsu.edu/ and https://www.chronicle.com/article/Georgia-State-U-Made-Its/243514. Note that "intrusive advising" is a term widely used in student affairs.

experience identifying effective interventions when students encounter academic, financial, or other difficulties. While it has proved challenging to repeat Georgia State's full success elsewhere, many universities are moving toward more intrusive and holistic advising models that consider academic, financial, and social factors in students' success.

Another consideration for student success is the amount of flexibility or rigidity present in the path from initial interest in physics to eventual graduation. Our site visits showed that many African American students did not enter college intending to major in physics but were drawn to the department by inspiring classes or by peers who invited them to club events. For those colleges and universities that recruit heavily from two-year colleges, having multiple entry points is crucial; for example, introductory mechanics can be offered in both algebra-based and calculus-based versions. A first-year seminar introducing students to the practice of science and engineering was helpful at several campuses we visited. Even more valuable was having a choice of curricular pathways. For example, Morehouse College, which does not have a separate engineering department, offers students the possibility of a dual degree in engineering at a partner research university. We found that some students were drawn to physics because of its connection to engineering but later decided they preferred physics itself, and so moved out of a dual degree program onto a pure physics track.

Other Recommendations

3c. Faculty and staff serving as undergraduate advisers should work closely with central advising offices to ensure that students facing academic, financial, and other difficulties can find the support they need.

3d. Departments should regularly and quantitatively assess their recruitment activities and curricular pathways, identify points at which students leave before graduation, and develop evidence-based, actionable plans to increase the persistence of all students to the degree.

3e. Departments should provide information about support services written in a manner accessible to and understandable by all students.

In our site visit to Georgia State, we observed that the physics and astronomy students benefited from the advising support put in place by the central university and by the College of Arts and Sciences. We also learned that a crucial element was the close partnership between the department, the College, and the University Advisement Center. Having a faculty member knowledgeable about the department's curriculum, instructors, and individual student needs ensures that students receive appropriate advising through the combination of professional advising from central offices and faculty guidance in the department. At Morehouse College, the department chair and other faculty are aware of students' individual needs and even financial situations and intervene with help as necessary, including contacting students in their residences. Whatever a university's advising system is, faculty input can be very helpful regarding a student's academic needs, and, more generally, as part of a personalized support network for each student. When appropriate, departments should invite representatives from key support services to student events so that students can make direct contact with individuals in the department context. Faculty at Predominantly White Institutions have much to learn from their colleagues at HBCUs, where such support systems are especially strong (Arroyo and Gasman 2014).

Departmental self-assessment is practiced sporadically in most physics departments, generally in preparation for external reviews. A good practice aligned with our findings about the benefits of multiple curricular pathways is to regularly collect and analyze data on undergraduate majors' progression through the curriculum. Ideally, for all physics and astronomy majors the department would track the physics or astronomy classes completed at the time they entered the major, their progress through milestones, and their exit points (for those leaving the major or failing to complete a degree), all disaggregated by race/ethnicity/gender. Even a "bolometric" measure comparing the fractions of enrolled majors by race/ethnicity/gender (which is collected by all universities and reported annually in aggregate form to the National Center for Education Statistics), with the same fractions for students graduating with bachelor's degrees, is highly informative. More detailed information on progress through the curriculum can help a department to identify and solve problems that hinder degree completion for African American students.

Recommendation 3e calls for departments to provide information about support services in a manner accessible to and understandable by all students. Having students review the information and participate in updating and disseminating it can help make this contribution to advising more effective.

FACTOR 4: PERSONAL SUPPORT

Many African American students need support to offset financial burdens and stress.

Our student survey identified some significant barriers to the persistence and success of African American students that physics departments do not create and may be unaware of. These were particularly clear in the analysis of respondents who expressed an intention to transfer to another university, to stop out (take a break for one or more terms with the intention of returning), or to change majors.

Key Findings

4a. Financial stress is particularly high for many African American students given the documented enormous racial wealth disparities in the US. Colleges and universities improve student retention and graduation by providing emergency support.

4b. Working on or off campus in a paid internship or a job related to their major, such as paid research, enables students to earn needed income while supporting academic progress.

Our student survey showed that while respondents from all racial and ethnic groups reported concern about paying for college and the extent to which working for pay interferes with studies, African American students were the most concerned about paying back their debt (Appendix 2). Moreover, in our survey findings, answers to open-ended questions, and focus group data, finances were the barrier most frequently cited by African American students. While not representative of everyone, one student's circumstances illustrate the challenges and unique situations that some students can face while in college:

> **"I am paying the cost of college on my own, so that is continuous financial stress. Working 20-plus hours a week, including overnights. Continuous and worsening mental health issues. Personal tragedies. Living at home in a nonideal situation. Lack of support from the college/department. Administrative issues with the college."**

The continual stress of worrying about money to pay for school and the mounting debt cut across a number of the comments in our survey responses and impacted all aspects of students' lives, including dealing regularly with a lack of sleep. At several schools we visited, physics faculty who learned about student financial stress were able to obtain emergency funding to assist those in need. But our research indicates that such efforts, while appreciated, do not come close to eliminating financial stress.

While our student survey shows that financial concerns are greater for African Americans than for other respondents (Figure 17), the statistical significance is weak. However, our sample is missing the very students who would most reveal the financial burden: the estimated 150 African American students per year who are missing because of the decline in HBCUs during the past 20 years relative to physics overall (discussed in the next chapter). Our site visits showed pervasive financial challenges for African American students at Predominantly Black Institutions. Moreover, many African American students are choosing to pursue engineering degrees (or a dual degree, as offered at Morehouse College) rather than a physics or astronomy degree, at least in part because of perceived greater financial rewards.

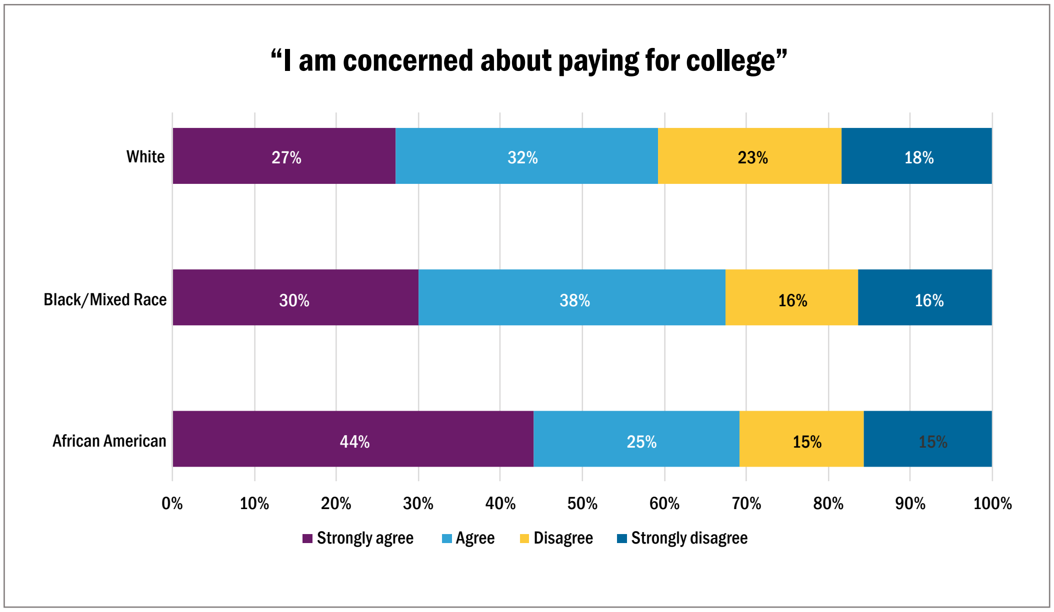


Figure 17: Student concern about paying for college by race. African American students had greater concern about paying for college
Source: TEAM-UP Student Survey

The reason for these financial concerns is not difficult to find. The US Federal Reserve Board (Bricker et al. 2017) reported that the median wealth of White families in the US in 2016 was 10 times that of Black families (and 8 times that of Latino families). This enormous racial wealth gap places a heavy burden on most African American students, who accumulate high levels of debt attempting to graduate from college (Center for Responsible Lending 2019).

Students in our site visits emphasized the importance of having aid in the form of stipends, not just tuition support.

A promising solution for colleges is to provide paid research jobs or other on-campus jobs that advance students' academic progress. This is the philosophy of the Federal Work-Study Program, which emphasizes civic education and academics-related work and has been shown to increase college graduation rates (Scott-Clayton and Zhou 2017). However, financial aid and work-study together often do not meet a student's full need, which results in the student accruing greater debt or turning down federal work-study aid in favor of other employment (Baum 2019). Students in our site visits emphasized the importance of having aid in the form of stipends, not just tuition support. The latter has no impact on the hours they work to support themselves and family members while in college. In our survey, the majority of physics majors, including both African Americans and Whites, reported working for pay at least 10 hours/week. In our site visits, the majority of African American students we spoke with were working more than 12 hours/week (and some more than 30 hours/week) outside of their academic work in order to earn money to continue school or support their family. The resulting financial stress was a barrier for many students. Chicago State University and the University of Maryland both try to alleviate this stress for African American physics students through scholarship funding from the National Science Foundation S-STEM program.[16] Students may also have access to outside resources such as the APS National Mentoring Community BEAM fund.[17]

16 For information on this program, visit https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5257.

17 For information on this fund, visit https://www.aps.org/programs/minorities/nmc/nmcbeam.cfm.

Recommendations

4a. Departments should identify campus resources for emergency financial aid, conference travel, and other unmet needs and help students take advantage of them.

4b. Faculty should seek funding for undergraduate students to work in research groups or as Learning Assistants, and find other ways to help students advance academically while earning money.

Academic institutions have a responsibility for the care of their students. This responsibility lies not only with central offices like financial aid but also with departments, whose faculty and staff should share information with students about campus resources. Faculty can be especially helpful in reducing the stigma associated with financial strain (and other concerns) by candidly discussing their own challenges when they were students and the ways in which they navigated them.

Georgia State University's predictive analytics system informs advisers of students who are late making tuition or fee payments and provides advisers with information about an emergency funding mechanism to support these students. While this kind of system cannot originate in a department, faculty advisers can work with their financial aid offices or others in the university to achieve the same result.

The Lumina Foundation report *Beyond Financial Aid* provides good advice to academic administrators on ways to provide holistic support for students facing financial strain (Lumina Foundation 2018). While the report is written for central offices, many of its suggestions and self-assessment tools are helpful to departments—for example, its guidance on ways to create a culture of support for students.

Most physics and astronomy faculty strive to integrate research and education and regularly seek external funding for these purposes. They may not consider, however, the greater needs of—and hence the larger impact of providing funding to—students who are low income, first generation, and/or racial or ethnic minorities.

Other Key Findings

4c. The need for mental health care is increased by financial and family stress (e.g., illness or death of a family member). Faculty and staff can normalize seeking help by discussing stress and self-care with students and referring them to campus resources.

4d. Student retention improves when faculty recognize students as individuals with unique and intersecting social identities and experiences, such as being a first-generation college student or working to support a family.

Anxiety, stress, and depression are growing concerns on college campuses, especially for marginalized group members. Research shows that more than half of first-year African American college students report feeling overwhelmed most or all of the time (Steve Fund and Jed Foundation 2017). They face mental health challenges that can be exacerbated by racial microaggressions and bias experienced disproportionately compared with other groups.

The following student comment illustrates the complex ways in which mental health challenges are exacerbated by financial and family stress:

> **"Having to work many hours to support my family. Both of my parents had [life threatening illnesses] around the same time. Then [one parent] passed away ..., [the other parent] survived …, and the government mistakenly [mislabeled my status]. My mental health was at stake because I couldn't remember any physics or math to do [my] research."**

As this and other student comments indicate, mental health concerns often do not arise in isolation. Conversations with faculty and staff in some of our site visits indicated their awareness of mental health concerns and the complex interplay of mental health with financial and family matters. They were also aware of the skills needed to speak caringly with students and guide them to professional support. In general, mental health concerns were raised more often by White students than African Americans in our survey; however, African American students' experience of stress and mental health issues was more often tied to financial pressures.[18]

As noted in the sections on Belonging and Physics Identity, faculty play a key role in welcoming students into the department. However, it is not enough merely to invite students in, especially if their social identity does not conform to stereotypes of who is a physicist. Minoritized students must continually navigate the incongruity of their social and physics identities. This is especially the case for students with multiple marginalized identities, such as, for example, queer African American women, who must deal with overlapping systems of oppression. Faculty have a responsibility to eliminate toxicity in their departments and to create a culture in which African American students belong, can identify as physicists or astronomers, and are supported academically and personally to succeed.

In our site visits, one White faculty member stressed the importance of listening to students: "Students are the greatest experts in their own experience." African American students in that department reflected back this sentiment, noting that they felt heard and valued as individuals, in spite of—or perhaps even because of—the

18 Gender identity is the most significant social identity factor in mental health needs. Transgender, gender nonconforming, and bisexual students are much more likely to have mental health disorders than cisgender heterosexual individuals. See https://www.psychiatry.org/File%20Library/Psychiatrists/Cultural-Competency/Mental-Health-Disparities/Mental-Health-Facts-for-LGBTQ.pdf.

many challenges involving social class, age, race, gender, etc. that they faced and overcame. The high degree of faculty commitment inspired them to an even stronger determination to complete their physics degrees. The ease with which the faculty were able to acknowledge and support intersecting identities to reduce the overlapping oppressions of students with those identities made the students feel that they could be whole persons doing physics. These are the types of interactions that fortify important relationships with faculty and ultimately allow students to find congruity in all aspects of their identity as physicists.

“Students are the greatest experts in their own experience.”

Our site visits revealed an important way that institutions can help students bring their whole selves to the department: create opportunities for students to discuss broader societal issues of concern such as gun violence, immigration, hate crimes, and protest movements. This works best when faculty and other community members also attend to and validate the concerns of students.

Other Recommendations

4c. Faculty and staff should normalize seeking help by discussing stress and self-care with students and referring them to campus resources.

4d. Faculty should strive to understand that students do not leave behind their identity and experiences when entering the classroom and should recognize the unique promise of each student from a perspective of strengths rather than weaknesses.

4e. A consortium of physical sciences societies should be formed to raise a $50M endowment from foundations and individuals to support minoritized students with unmet financial need in physics and astronomy and to support the implementation of this report’s recommendations by departments. As an interim step, physics and astronomy societies should raise $1.2M per year to relieve the debt burden of African American bachelor’s degree students.

...learning to focus on students’ strengths rather than weaknesses can help faculty to give more effective feedback.

In our site visits we saw examples of faculty discussing sleep, emotional well-being, and mental health needs with students in ways the students found encouraging and helpful. Normalizing conversation around such personal topics helps build students’ sense of belonging and increases the likelihood they will seek help if they need it, especially when a faculty member walks them to the counseling center. The Equity in Mental Health framework (Appendix 10) helps administrators interested in taking additional steps to support the emotional well-being and mental health of students of color.

We have already emphasized the benefits to students of faculty that acknowledge their whole selves. Developing the listening and intercultural skills to achieve this requires the same kind of practice as any other professional skill physicists must develop. Faculty can find support for developing these skills via campus centers for teaching and learning; student affairs offices; or institutional offices of diversity, equity, and inclusion.

Even small steps to shift one's perspective can be very helpful in supporting students. For example, learning to focus on students' strengths rather than weaknesses can help faculty to give more effective feedback. This was especially striking in our site visits to the most effective departments, where faculty consistently focused on student growth instead of the lack of preparation some African American students might have. "Our students are our strength" was an inspiring message shared by a faculty member.

As discussed above, the degree of financial stress and the concomitant need to work were the largest distinctions between African American students and others in our survey and site visits. To understand why, we note the enormous wealth disparity in the US between African American and White families. Using data from the triennial Survey of Consumer Finances, the US Federal Reserve Board reported that in 2016 the median wealth of White families in the US was $171,000, while that of Black families was $17,600 and $20,700 for Latinx families (Bricker et al. 2017). This enormous inequality is also reflected in the financial hardship of HBCUs compared with Predominantly White Institutions (Williams 2010, Schexnider 2017) and in the greater tuition debt burden held by African American students compared with others (Espinosa et al. 2019, Center for Responsible Lending 2019). Although these problems go far beyond the physics community, there is an intervention our community could take that would make a big difference for African American physics students.

Physics and astronomy professional societies have strong convening power and influence within their fields. They, more than individual physics departments, have the potential to raise significant funds to support African American students facing financial hardship. The case for a $50M endowment, producing an annual income of $2.5M, is made in the next chapter, as is the case for a lesser annual payout of $1.2M. The fund-raising, endowment management, and award selection should be done by a new nonprofit organization created for this purpose. The task force believes that the fulfillment of this recommendation would do more than any other measure to increase the number of physics and astronomy bachelor's degrees awarded to African Americans.

FACTOR 5: LEADERSHIP AND STRUCTURES

For sustainability, academic and disciplinary leaders must prioritize creating environments, policies, and structures that maximize African American student success.

Given the autonomy and independence of many faculty members—common features of higher education—and the focus on research in most physics departments, who is responsible for increasing the numbers of physics bachelor's degrees to African American students? Who is capable of doing it? Who effects change?

To begin to answer these questions, we can examine a parallel discussion in the recent National Academies report on sexual harassment of women in academic sciences, engineering, and medicine (NASEM 2018a). This report has a chapter devoted to "Changing the Culture and Climate in Higher Education." In the next chapter we address culture change. Here we focus on the simpler question of how to effect change in a department, with findings and recommendations similar to those in the NASEM (2018a) report, scaled to the departmental context.

Key Findings

5a. Department chairs and officers can set norms and values; recruit, develop, and support faculty; and oversee structures, policies, and practices that enhance or diminish the success of African American students.

5b. Departmental initiatives can provide a scaffolding for student belonging, physics identity development, and academic support.

Our site visits highlighted the importance of departmental leaders in any major initiative or change. When we asked faculty in departments that were highly successful in graduating African American physics students how they achieved their strong collective results, several noted that their department recruited faculty whose values and vision were aligned with the department's mission. The department chair is the one who represents the department's mission. Department chairs are stewards of the faculty, they play a key role in articulating the department's norms and values, and they and other departmental officers are responsible for determining who does the work, what policies guide the work, and what practices are rewarded in the education of African American and other students.

When we asked faculty in departments that were highly successful in graduating African American physics students how they achieved their strong collective results, several noted that their department recruited faculty whose values and vision were aligned with the department's mission.

Chicago State University's Department of Chemistry and Physics has adopted many, if not all, of the high-impact practices recognized in the findings and recommendations discussed above. Implementing one reform at a time starting from the beginning would be very difficult. Instead, CSU has introduced programs and organizational structures that provide support for everything else, a kind of scaffolding upon which an ever-widening inclusive and equitable environment for students grows. The Chi-Sci Scholars program (Sabella et al. 2017) is the backbone of this effort.

Recommendations

5a. Department chairs and officers should set norms and values of inclusion and belonging; recruit, develop, and support a diverse faculty; and oversee structures, policies, and practices that enhance the success of African American students.

5b. Departments should identify, partner with, financially support, and advocate for campus programs like McNair Scholars that may already provide a scaffolding for student belonging, STEM identity development, and academic support of African American students.

Finding 5a noted that department chairs and officers *can* do things (indeed, they do these things at the departments we visited); Recommendation 5a replaces *can* with *should*. In some institutions, physics department chairs might not perform such functions, for either structural or cultural reasons. We urge all departments to take advantage of university accreditation reviews or other self-study processes to engage these issues so they can find ways to implement Recommendation 5a and the other recommendations of this report. A first step that departments can take is to establish a departmental values or vision statement.

Many campuses already have programs that provide academic, social, and personal support for African American students, including physics majors, such as the McNair Scholars program.[19] Physics departments can demonstrate their commitment to African American students by highlighting the accomplishments of these scholars, recruiting new students to join them, partnering with them in campus and community events and providing funding for these, and advocating for their needs with institutional leaders.

Other Key Findings

5c. Department connections to university- and college-level resources such as student affairs offices, dual-degree programs, research funding programs, multicultural centers, tutoring centers, etc., help to increase student awareness and usage of these valuable offerings.

5d. Lone champions can make a big difference for students, but their effort is unsustainable, making this an ineffective long-term strategy. In the most successful departments, a significant fraction of the faculty consistently value and support underrepresented students.

Finding 5c is an elaboration of finding 5b to recognize the impact of support outside the academic departments. Virtually all colleges and universities have programs and offices to support the academic and personal needs of students. The engagement of departmental faculty and staff with these programs helps them to be more effective. We saw this in our site visits, where many faculty were well connected to programs like those listed above.

In some institutions, including those that some task force members have been part of, a single faculty champion undertakes heroic efforts to support and advocate for students in such ways as we have recommended above. While one advocate is better than none for the students, it is a poor model for many reasons. Often the champion is a member of a marginalized group who feels compelled to take prosocial action that helps students better navigate a system that was not created for them. When such efforts are not valued by department norms, they are impossible to sustain. In many cases the faculty member burns out, fails to get tenure, retires, or departs for a more supportive environment. This is typically followed by abandonment of the entire scaffold of support that existed through that person's unique efforts. The most successful departments for students that we visited had *many* physics faculty members acting as champions for African American students; indeed, this was baked into the culture of the department to such an extent that the risk of reliance on a single champion was eliminated.

19 Ronald E. McNair was an African American physicist. A graduate of North Carolina A&T University, he obtained his PhD in physics from MIT. As an astronaut, he died in the Challenger disaster of 1986. After his death, Congress directed the US Department of Education to fund a program in McNair's name to prepare students from low-income, first-generation, or underrepresented groups to prepare for PhD programs.

Another common challenge is the periodic turnover of department leadership, resulting in a loss of experience and, potentially, a loss of commitment to African American students. The most successful departments that we visited (or that task force members have been part of) prepare potential leaders long before they become chair, collectively create and regularly discuss a shared vision for the department, and rely on past chairs as senior advisers. In these ways, the values and practices that support marginalized students become institutionalized.

Other Recommendations

5c. Departmental administrators should become familiar with and encourage students to utilize campus resources including student affairs offices, dual-degree programs, research funding programs, multicultural centers, tutoring centers, etc.

5d. Department chairs should provide incentives and rewards to multiple faculty members, including those who are not members of marginalized groups, who actively support underrepresented students.

5e. Professional societies should encourage existing and new groups within their organizations, such as the new APS Forum on Diversity and Inclusion, to examine ways to advance the recommendations of this and similar reports.

Recommendation 5c follows directly from the corresponding finding. Given the relatively rapid turnover of faculty in relevant teaching and service roles, it is wise to assign the responsibility for departmental connections with campus resources to administrative staff in the department.

Recommendation 5d presumes that department chairs have some ability to incentivize and reward faculty. If a department has a major initiative, it is likely that the chair has used incentives and/or rewards to foster that initiative. These may include course releases compensating for the time faculty put into advising students or launching the initiative, seeking seed funding, and advocating with the dean or provost for such funding; they may also include departmental awards or nominations for external awards and prizes. The use of such mechanisms for other initiatives in the department, whether or not they are intended to advance the numbers and success of African American undergraduates, is an indicator of departmental commitment.

Recommendation 5e recognizes that physics faculty and departments are part of a larger system in the physics community, one in which professional societies play an important role. For example, professional societies are a primary source of external awards and prizes that a department chair nominates faculty for. They also provide spaces for faculty to exchange results and ideas in research and education, to network, and to create a shared vision for the larger profession. The bodies represented by the AIP's Liaison Committee on Underrepresented Minorities (LCURM), which proposed the creation of this task force, are an excellent starting point for advancing our recommendations through efforts by the professional societies. More discussion and further recommendations related to the professional societies appear in the next chapter.

A Call to Action

In 1946 Albert Einstein wrote to the annual convention of the National Urban League,"The worst disease under which the society of our nation suffers, is, in my opinion, the treatment of the Negro." Earlier that year, in a speech at Lincoln University, an HBCU in Pennsylvania, he called racial segregation "a disease of white people" and stated that "I do not intend to be quiet about it." (Jerome and Taylor 2005). Almost two-thirds of a century following the end of legal segregation in education with *Brown v. Board of Education* in 1954, racism remains an American disease that we as physicists must address if we are to increase the numbers of African American physics graduates.

Figure 1: Albert Einstein at Lincoln University in 1946.

Einstein certainly understood that the physics community did not create racism. Yet Einstein also understood that racism was preventing the nation from reaching its highest potential and that White America had to play a role in the eradication of racist policies and practices. As we recognize 400 years since the first enslaved Africans were brought to North America in 1619, the persistence of racism in the US makes it even more important that we understand this historical context. Increasing the number of African American bachelor's degrees in physics is a challenge that cannot be met by individual champions acting in isolation; it cannot be achieved by the efforts of a few outstanding physics departments; and it cannot be accomplished without understanding the system of racism that suppresses equity in America. As for our role, we believe that physicists are, fundamentally, people who choose to analyze systems; who produce tools needed for change; and who love to solve problems, especially ones whose solutions advance our ability to solve still harder problems.

The reasons why physics bachelor's degrees awarded to African Americans have stagnated since 1995 while other disciplines and racial and ethnic groups have shown increases (Appendix 1) are systemic in nature, involving many interrelated processes operating on individual, institutional, and societal scales. We have described many of the causes in the previous chapter, focusing on the experiences of physics students in colleges and universities. Other factors contribute to extreme racial wealth disparities (Bricker et al. 2017), including many decades of housing discrimination, unequal K–12 educational systems (White and Tyler 2015), and mass incarceration. While not originating within higher education, these inequities affect African American students across all disciplines (Espinosa et al. 2019; Morsy and Rothstein 2016).

At the end of the 1990s, when physics enrollments had dropped precipitously across the country, the physics community did not just lament that there was a societal problem affecting all of the STEM fields (except psychology and life sciences) whose solution was beyond our control. Instead, the SPIN-UP Project was launched to determine what physicists could do to solve their own discipline's problem (Hilborn, Howes, and Krane 2003). The success of that effort is clear after nearly 20 years. For all STEM fields, the number of degrees awarded in 2017, divided by the number awarded in 1999, is 1.98. For physics that ratio is 2.50.[20] Yet within the context of this overall remarkable rebound in physics bachelor's degrees, the data and this current study reveal a sobering truth about physics and astronomy: while physics has shown great success in recruiting and granting degrees to White males, we have, over the same period—through either neglect, indifference, or worse—driven out some African Americans from US undergraduate degree programs. We believe that the SPIN-UP report was crucial to the success in physics, and we believe that physicists can now rise to the challenge of recruiting and retaining African Americans to degree completion.

It is our fervent hope that the physics and astronomy communities will excel among all fields by increasing the representation of African American undergraduates over the next decade. This effort will be successful only if these communities make cultural and systemic shifts to create a sense of belonging and ensure equitable access to resources and opportunities. Increasing representation is easy to measure, so it is tempting to focus solely on that goal. However, increasing access without attending to equity is to set ourselves up for failure. This final chapter presents the first and most important steps that we feel the physics and astronomy communities must take to demonstrate leadership. We begin with background and recommendations for managing cultural change.

Change Management

A new level of thinking is required to solve a persistent problem.

The causes for low African American bachelor's degree production are complex and involve interactions among individuals, academic departments, and colleges and universities; the norms and practices within the physics and astronomy communities; and society at large. To be successful, interventions must also be systemic, applied at multiple scales, and managed with an understanding of their interactions. Physicists and astronomers are trained to think in such ways, making this an intellectual and social challenge worthy of their best efforts to solve.

Increasing the number of African American bachelor's degrees in physics and astronomy will require effort by departments of all different types across the US. However, without the support of outside groups it would be difficult to motivate and prepare departments and impossible to assess and sustain these efforts. A collective problem calls for a collective solution. More than any other groups, the disciplinary professional societies are well placed to inspire, introduce, assess, and sustain the change process. This section discusses important ways in which the professional societies and individual departments can work together to create lasting change.

---

20 Source: https://www.aps.org/programs/education/statistics/bachelors.cfm

Effective change takes place within a multiscale system that includes relevant professional societies, individual departments, faculty, members, and students as units in the system. Important interactions occur within every organization and between every unit.

As physicists and astronomers, our first instincts in addressing any challenge may be to identify the components and their interactions, create a model, find the governing equations and the requisite initial data, and iteratively solve to find the inputs needed to produce the desired output. Adapting this approach to the social problem of underrepresentation might look like this: a vision is set, a strategic plan is created, recommendations are pursued, the results are assessed, and the system is iteratively modified for optimal success.

Sadly, this approach has not worked in the past for African American students, and we do not expect it to work now. As department chairs and other academic leaders quickly learn, things rarely work out in such a linear fashion when it comes to changing behaviors and outcomes. Assuming that they will do so often leads to frustration and disappointment (Dobbin and Kalev 2016).

Following this realization, one's inclination may be to give up, under the assumption that the problem is either too difficult to solve or not worth our efforts. This conclusion is equally flawed. A better approach is to examine the literature on institutional change, identify successful change efforts of similar scope and nature, learn from the experience of the changemakers, and pursue similar strategies. Fortunately, much of the groundwork has been set by sociologists who study organizational change in higher education. A recent comprehensive report on STEM in higher education (NAS 2016) devotes a full chapter to this topic, including the physics community's SPIN-UP report and process as an example of a successful change effort (Hilborn 2012). Other examples are given by education researchers (Elrod and Kezar 2016, 2017; Vinkenburg 2017).

Why is systemic change difficult, and what can physicists do about it? To answer the first question, it is helpful to distinguish between two types of institutional change (Kezar 2014). First-order institutional changes are those that modify processes to better achieve an established goal. Second-order changes are those requiring that underlying norms, values, and culture be addressed before changes can occur.

Large-scale efforts in high-energy physics illustrate these two models. Building the Tevatron at Fermilab was an example of first-order change: the goal of completing the Standard Model of particle physics was clear and compelling in the high-energy physics community; the Tevatron could achieve this goal (except, of course, for finding the Higgs boson); and it could be built via existing planning and funding mechanisms. By contrast, building the Superconducting Super Collider, whose purpose was to find the Higgs or another mechanism for symmetry breaking in the Standard Model, required second-order change. Different subfields of physics held different values about what was most important and different norms about how physics research should be conducted. Building the Superconducting Super Collider required a wider consensus in the scientific community as well as among political leaders. This did not exist, in part because of disparate values and cultures in high-energy physics, in other subfields of physics, and in the US Congress. The Superconducting Super Collider project was terminated in 1993 after $2 billion had been spent, in part because physicists were unprepared for second-order change.

A common error in work on diversity, equity, and inclusion is to use methods suitable for first-order change (strategic planning, creating and charging committees, providing staff support) to address problems that require second-order changes. Resistance arises because people do not understand the need for, or nature of, the change. Probing deeper, the change may conflict with deep-seated values. Acknowledging systemic problems is a key feature of the change dynamic. No strategic plan will succeed without first getting buy-in from the stakeholders concerning the nature of the problems to solve.

Before undertaking such challenges, experts in change management recommend the construction of a theory of change (Kezar 2014), a "comprehensive description and illustration of how and why a desired change is expected to happen in a particular context."[21] A theory of change differs from a logic model in that it considers a much broader context than the typical Gantt chart used by project managers. Theories of change consider norms and values, culture,[22] policies and procedures, leadership, social power, external context, and additional factors.

Kezar (2014) describes six categories of theories of change: scientific management, evolutionary, political, social cognition, cultural, and institutional. Our analysis suggests that achieving the goal of at least doubling African American physics bachelor's degrees within 10 years will require, at a minimum, elements of social cognition (understanding how physicists can develop a shared understanding of the need for change and the appropriate mechanisms to accomplish that change), political considerations (the need to build relationships, create coalitions, and examine social power and influence), and culture (examining norms and values, learning and utilizing the power of storytelling). This approach is quite different from a traditional strategic plan, which is based much more on scientific and institutional management practices, which are inadequate for creating second-order change (Kezar 2014). Scientific management and institutional theories of change are helpful, but when culture change is needed, using them alone leads, at best, to "box checking" solutions.[23]

The goal of our efforts is to eliminate the gap in African American physics and astronomy degrees through systemic interventions and culture change in our communities. As noted in the Introduction and Appendix 1, a doubling of these degrees is necessary to achieve parity with the increases for other racial and ethnic groups during the past two decades. Ten years is a short time over which to achieve this doubling, but we are optimistic that a concerted effort utilizing the processes of change discussed below, and incorporating the recommendations made in the previous chapter, can lead to success.

Recommendations

6a. Professional societies and individual departments should each develop a theory of change utilizing sensemaking and shared leadership. The societies should hold discussion forums on this topic. Additionally, representatives from all groups should jointly produce a unified change management model highlighting the interactions among the societies, universities, departments, and individual physicists and astronomers needed to support their efforts.

---

21 Definition from https://www.theoryofchange.org/what-is-theory-of-change/

22 Culture can be understood as "the social behavior and norms found in human societies" (Wikipedia), as applied to organizations. In Beamtimes and Lifetimes (1988), anthropologist Sharon Traweek famously noted that physicists believe there is no culture in their profession. The task force believes that many physicists think they are fully objective and unaffected by culture, or they conflate culture with climate.

23 Box checking is the practice of adopting recommendations without changing the underlying norms, values, and culture of an organization.

6b. Departments should review and learn from related reports and programs of other science and scholarly organizations including the AAS (Nashville Recommendations, Diversity and Inclusion in Astronomy Graduate Education), APS (LGBT Climate in Physics, Effective Practices for Recruiting and Retaining Women in Physics, Effective Practices for Physics Programs, and the APS Inclusion, Diversity, and Equity Alliance), AAPT (New Faculty Programs), AAAS (SEA Change institutional awards and a parallel Physics and Astronomy SEA Change departmental award planned by disciplinary societies in the physical sciences), AAC&U (Project Kaleidoscope), and the National Academies of Science, Engineering, and Medicine (Sexual Harassment of Women, The Science of Effective Mentorship in STEMM).

Recommendation 6a calls on the physics and astronomy communities to use evidence-based change management methodologies described more fully below. As Recommendation 6b implies, the decline of African American bachelor's degrees is not the only challenge and opportunity in diversity, equity, and inclusion facing physics and astronomy. The reports and programs listed in Recommendation 6b overlap significantly in themes and content with this report, and they recognize similar efforts by many organizations in our community. To prevent information overload, the professional societies should help departments customize their efforts based on self-assessment and prioritization.

Before starting these efforts, it is necessary for stakeholders to educate themselves about the issues affecting underrepresented groups, how change happens, and what kinds of change our professions seek. As noted above, a sufficient theory of change for increasing African American physics and astronomy bachelor's degrees should, at least, incorporate social cognition, political analysis, and cultural factors.

In line with this, our site visits identified two features of the most successful physics departments that are also highlighted in the change literature (e.g., Elrod and Kezar 2016) and that seem even more important when working across the multiple levels of working across the multiscale system referenced earlier. The first is *sensemaking*, which is a learning process of creating meaning around concepts and ideas through a variety of social inputs including dialogue with others. An example is extracting understanding from a departmental climate survey. In reviewing the summary responses, a White faculty member, for example, can become sensitized to the marginalization of students of color. Merely seeing the survey numbers, however, is insufficient; the faculty member learns from research, from reflecting on their own experience, and from discussion with others, all of which may happen at a facilitated departmental discussion. This sensemaking leads to a newfound awareness, which may cause a faculty member to change his or her behavior toward students of color. Many diversity, equity, and inclusion efforts fail because stakeholders do not have a common understanding of or vision for the change. Sensemaking is a key element of social cognition theories of change; research shows that it is essential for second-order change (Kezar 2014). The best-performing departments for African American students regularly practice sensemaking to achieve a shared vision and understanding.

The second feature of the most successful departments concerns who leads change. Organizational change is often viewed as being driven by leadership, usually top-down but sometimes bottom-up. Rarely is one direction sufficient to create second-order change. Simplistic management practice assumes that the top leader of an organization can drive change. This usually does not work in higher education because of the power of individual faculty members over what happens in the classroom, the research lab, and the search committee. The same decentralized organizational structure that supports academic freedom precludes management from enacting change by decree. Bottom-up leadership from faculty, staff, and students is

critical because without it, top leadership lacks a full understanding of the concerns of the people who can drive change at the local level, being too far removed from the classroom and daily interactions among students and faculty. Bottom-up change initiatives also provide a natural accountability mechanism for any change effort.

In *shared leadership*, top-level leaders collaborate equitably with bottom-up change agents (Kezar and Holcombe 2017). From a social justice perspective, bottom-up leadership drives improvements in equity; those with the least social power play a role in creating change that serves their needs (Avila 2010). But those with little power can succeed only if the leadership supports their efforts. Within universities, and specifically physics and astronomy departments, this often happens when students advocate for change. Effective faculty leaders know that their success is contingent on the success, satisfaction, and well-being of their students. One of the major features of political theories of change is that they recognize the importance of sharing leadership across power hierarchies. In the most successful departments for African American students, the students themselves, as well as junior faculty and staff, are engaged alongside senior faculty in shaping departmental culture and practices.

Sensemaking and shared leadership are not taught in physics or astronomy graduate programs. Physicists can read about them in the books and articles cited above. They can also get a sense of their relevance by reviewing some of the many reports and initiatives that have recently been launched by the professional societies listed in Recommendation 6b.

Although it is important for individual departments and professional societies to construct their own theories of change, this alone is insufficient when these groups have to collaborate. To foster collaboration and a shared governance and ownership of the change process, we recommend that the physics and astronomy societies host a series of leadership forums and discussions on important cultural shifts and changes in their professions that will be key factors to be included in a theory of change for the professions. To be effective, these events must themselves demonstrate shared leadership by engaging marginalized group members in the leadership and programming and in the visioning process that follows. The resulting theory of change should be constructed not only to increase the numbers of African American students, but also to broadly address issues of equity, inclusion, and representation in physics and astronomy. The shared understanding resulting from such discussions can then inform the profession broadly, with each campus and unit modifying and adapting it to its unique context.

We recommend that all academic physics and astronomy organizations—including university and college departments, large research labs and collaborations, and professional societies—establish groups to engage in learning, practice, and action on this and similar reports. Ideally, these groups would include people of different demographic and social identities and power in the organization (e.g., tenured and untenured faculty, students, postdocs, staff, and administrators of various race/ethnicity/gender and other identities), and would utilize a facilitator trained in the requisite skills to help the group work effectively across social identities and power differences. A common mistake is to assume that well-intentioned faculty, especially those already in leadership roles, can manage such a team without external (and therefore independent and unbiased) help. The Departmental Action Team model (Quan et al. 2018) provides an excellent framework for facilitated sensemaking and shared leadership that can be adopted in multiple settings. If an organization wishes to start with a more homogeneous group, the faculty learning community model (Cox and Richlin 2004) is a good starting point for sensemaking. The APS Inclusion, Diversity, and Equity Alliance (APS-IDEA) utilizes online learning communities and will provide support to physics departments wishing to undertake culture change based on sensemaking and shared leadership.

The theory of change should pursue the common goals of increased numbers of physics and astronomy bachelor's degrees awarded to African American students and a change in the cultural norms that drive them out or inhibit their success. We intentionally do not remark on the level within the multiscale model at which the theory of change is developed, since the organizations may deem it necessary to work entirely at the societal level or to partner with one another or with academic institutions.

The sensemaking team should plan to spend at least six months reviewing their own organization (or set of organizations, if the team spans several) and talking with others to understand their local context, and up to another year digesting the many relevant reports and programs of relevant professional societies. University-based groups must consider the broad context of their institution, which very likely includes offices and teams already working on many topics related to equity, diversity, and inclusion. Teams that rush to action prematurely are often forced to backtrack to develop relationships and understanding of why resistance develops among key institutional stakeholders (Elrod and Kezar 2016).

Other Recommendations

6c. The professional societies should empower and prepare change agents by establishing and participating in faculty networks, learning communities, and skill-building workshops, including organizing sessions at their annual meetings to discuss this and related reports.

6d. The professional societies should establish or increase rewards and incentives for efforts by faculty members to improve the success of African American students (and other marginalized group members, who are not the focus of this report) in physics and astronomy.

6e. The professional societies and individual departments should gather relevant quantitative, qualitative, and descriptive data about their organizations, disaggregated by race/ethnicity/gender, as appropriate. Some organizational body, to be determined, should assess and publicly communicate progress toward the recommendations of this report every two to four years with both quantitative and qualitative data similar to those used in this report.

The final set of recommendations concern the role of professional societies in leading change. Recommendation 6c concerns ways in which the professional societies support professional development and training of faculty. This builds on work currently done, for example, in the New Faculty Workshop hosted by the AAPT in conjunction with the AAS and APS, and in the associated Faculty Online Learning Communities (Lau et al. 2017). Increasingly, physics and astronomy professional society meetings include sessions on equity, diversity, and inclusion and on student learning. These topics are prominent in AAPT meetings; we encourage other societies to increase their efforts, including discussion of this report at meetings in 2020 and beyond. Committees within each professional society, including those represented in LCURM, are already in place to help advise these efforts.

Rewards and incentives are commonly used to support an organization's goals. Recommendation 6d recognizes that professional societies are especially important in shaping the culture of scientific disciplines because so much of the reward system (e.g., peer review of research publications, grant funding decisions, external evaluation for promotion and tenure) is based in the broader profession outside a scholar's institution. For these reasons, second-order change across the profession—in which norms and values shift—calls for a partnership among departments, universities, funders, and professional societies. Professional societies can lead the way by showing that equity and inclusion are valued.

An example of such second-order change related to honors and awards bestowed upon individuals, departments, and institutions is the recent discussion around sexual harassment in academic science, engineering, and medicine mentioned in the previous chapter (Recommendation 1e). In June 2019, after months of discussion and previous similar actions taken by the American Geophysical Union, the AAAS, and the National Science Foundation, the National Academy of Sciences changed its bylaws to allow revocation of membership for sexual harassment or other unacceptable behaviors (Feder 2019). The task force recommends that these organizations and other professional societies sanction unacceptable behavior and also do more to reward and incentivize actions that advance the professions' stated values of equity, diversity, and inclusion. Currently an abundance of prizes and awards are offered for research advances in specialized subfields of physics, many more than are offered in recognition of contributions to advancing stated values[24] of diversity and inclusion.[25] Whether intentional or not, this sends a signal as to the relative value of these efforts in the profession. As noted above, norms and values must be queried and shifted before second-order change can take place.

The final recommendation, 6e, is an umbrella for the important areas of assessment and accountability. The location and brevity of this recommendation should not be interpreted as a minimization of its importance. On the contrary, no success can be demonstrated or sustained without assessment and accountability.

---

24 See, for example, the 2019 APS Strategic Plan, https://www.aps.org/about/strategicplan/index.cfm.

25 In the APS, for example, awards include the Edward A. Bouchet Award and the Mentoring Awards of the Division of Nuclear Physics and the Division of Particles and Fields. The Maria Goeppert Mayer Award is for scientific achievement by a woman physicist, while the Bouchet Award criteria include the advancement of underrepresented minority physicists (eligibility is restricted to minority physicists).

The AIP has long gathered and reported information on physics and astronomy degrees through its Statistical Research Center. As our findings show, underlying these numbers are the student experience of belonging, the development of their physics identity, the supporting actions of faculty, and the leadership and structures of departments as well as broader campus resources. Characterizing all of these requires department-level assessment of climate (including qualitative data) and description of policies and practices (descriptive data). We urge departments and professional societies to gather and share data as appropriate. As an example, the AAS report *Diversity and Inclusion in Astronomy Graduate Education* (Agüeros et al. 2019) proposes a standard set of data that each department would gather. In addition, it recommends that the AIP conduct an astronomy-wide climate survey. Similar efforts could take place in physics. We encourage departments and professional societies to construct theories of change (Recommendation 6a) with assessment appropriate to their individual context. Self-assessment rubrics to help departments in this task are supplied in Appendix 8 of this report, as well as in the AAS graduate education report (Agüeros et al. 2019) and the Equity Scorecard and STEM Toolkit of the Center for Urban Education at USC (Appendix 10).

Providing accountability to the profession is an important role that the professional societies can take by periodically assessing and communicating progress toward the recommendations of this report. We note that the AIP Statistical Research Center has a long track record of assessing the state of African Americans in physics and astronomy.

Empowering Students

This report calls for significant changes in the culture of physics and astronomy. These changes will be neither easy nor quick. The research literature suggests that second-order change in higher education takes 7 to 10 years or longer (Kezar 2014), and often efforts toward change do not succeed. We cannot in good conscience wait for these improvements. Students need to experience environments in which they can learn, grow, and prosper, now.

In Appendix 9 we present a rubric to help high school students and their parents assess physics and astronomy departments before making a decision on college enrollment. Informed by our findings and organized by the five themes of this report, the rubric can be used during pre-college visits, especially in meetings with department chairs. Our framework should allow students and their parents to ascertain the strengths and weaknesses of physics and astronomy departments and the broader campus climate for inclusion and equity. This information will enable students to make more informed choices and thereby increase the likelihood of their success as physics majors.

If enough students begin using a tool like this, departments and universities will take notice and will be more likely to engage in the change process recommended above.

A Bold Vision

After two years of data collection and study, two factors stand out above all others in the success of, and challenges facing, African American physics and astronomy majors. The first is the importance of a supportive community, which is deeply present in HBCUs and PBIs but not in all PWIs. Even at the very successful PWIs that we visited, not all of the faculty were deeply engaged in improving outcomes for the students, or as caring

mentors for students. Based on the totality of the evidence, TEAM-UP concludes that the degree of care given to belonging, physics identity, and personal support largely explains why the top 10 producers of African American physics bachelor's degrees are HBCUs (Appendix 1), despite the much smaller size (and financial capacity) of their physics programs compared with those at large public and private universities.

The second critical factor is the enormous economic challenge facing African American students. At public four-year colleges and universities, 84% of African American students graduated with debt in 2015–16, and the median debt exceeded $30,000 (Espinosa et al. 2019, Table 7.13). The figures are even higher for private nonprofit colleges and universities (89%, $36,000). The median debt, and the percentage of students with debt, was less for other racial and ethnic groups (with the exception of Native Hawaiian or other Pacific Islander students at public four-year institutions, 85%). This level of debt can be viewed as an extension of the racial wealth gap that exists in the US (Bricker et al. 2017). The Center for Responsible Lending and the NAACP describe the student debt crisis as both a civil rights and an economic justice issue (Center for Responsible Lending 2019).

Students are not the only ones who experience racial wealth disparities; institutions do also (Williams 2010, Schexnider 2017). A recent issue brief by the American Council on Education (Williams and Davis 2019) found that HBCUs receive significantly less gift income and rely more heavily on federal, state, and local resources than do other institutions. Between 2003 and 2015, HBCUs saw a 42% decline in federal funding per full-time student. Moreover, their endowments are at least 70% smaller than those at other comparable institutions. *The very institutions that are most effective in graduating African American physics students can least afford to do so, and the students themselves have the least capacity of any racial and ethnic group to absorb the costs.*

These facts lead one to ask how to solve the financial challenge and thereby empower HBCUs (and PBIs, which may also face financial hardship) to contribute even more physics graduates than they already do. Restoring the level of physics degree production at HBCUs to what it was 20 years ago requires an increase of about 40 graduates per year (Figure 4 in Appendix 1). A more appropriate goal would be to increase it by the same factor by which PWIs increased their African American degree production over that same period, a factor of three. To reach this goal, HBCUs would need to increase physics bachelor's degree production by 150 graduates per year.

A minimal achievable goal would be to eliminate the debt burden on African American physics graduates, or about $8,000 per year per student. This would require $1.2M per year and would provide no relief to HBCUs. A more equitable goal would also provide a comparable amount of funding to HBCUs and other institutions contributing significantly to the education of African American students in physics and astronomy. This is how we arrive at a $50M endowment, whose yearly earnings of 5% would provide an annual income of $2.5M to help students and departments in need. Approximately half of the support would go directly to students and half would go to departments to support their implementation of this report's recommendations, although the exact allocation of funding should be decided following a peer review process evaluating requests from students and from departments. HBCUs and PBIs would be strongly encouraged to apply.

This, in turn, will help the physics and astronomy professions by graduating more African American students in those institutions that have the most promise for future success.

If the physical sciences profession were able to accomplish this goal, it would have a profound catalyzing effect across higher education. Other disciplines, many of which are much larger than physics and astronomy (such as mathematics, chemistry, biology, business, economics, and political science), would be inspired to match our efforts. Such efforts could ultimately prove transformative for HBCUs and thereby provide an appropriate way for contemporary physicists to advance the fundamental human rights of African Americans. By implementing all of the recommendations of this report, the physics and astronomy communities would honor the contributions of past, present, and future African American physicists and astronomers.

Detailed Listing of Findings and Recommendations

No priority is implied by the numbering of findings and recommendations.

FACTOR 1: BELONGING	Fostering a sense of belonging is essential for African American student persistence and success.

A sense of belonging is defined as an individual's feeling of being a welcomed and contributing member of a community. TEAM-UP's research on the student experience shows that fostering a sense of belonging is essential for African American student persistence and success. The recommendations emphasize the faculty role in fostering a sense of belonging.

Belonging: Key Findings

1a. Faculty interactions have a powerful effect on student retention in, or departure from, the major. Students' sense of belonging increases with the number of faculty who get to know them as individuals and demonstrate support for their success.

1b. Peer interactions are also very important, especially in mitigating or exacerbating imposter phenomenon and stereotype threat. When student clubs and organizations like the Society of Physics Students are inclusive and supportive of all students, they can provide valuable peer support.

1c. Peers of the same race/ethnicity/gender provide valuable social and academic support, often through counterspaces (e.g., family, churches, Black student organizations) serving as refuges from departmental cultures that are not highly supportive of African American students.

1d. Microaggressions and discrimination received from their peers diminish students' self-efficacy and persistence.

Belonging: Recommendations

1a. With the encouragement and support of their chairs, faculty should learn, practice, and improve skills that foster student belonging in their interactions with African American undergraduates.

1b. In classrooms, student clubs, and common spaces, departments should establish clear rules of engagement that ensure that everyone is welcomed and valued and convey that inappropriate behavior will not be tolerated. Departments should also provide spaces and opportunities for education and ongoing discussion among faculty and students on ways to actively foster a sense of belonging and reduce barriers to inclusion.

1c. Faculty who teach or advise undergraduates should become aware that counterspaces are important for African American students and should assist students in finding the support they need inside and outside the department.

1d. Departments should establish and consistently communicate norms and values of respect and inclusion. They should periodically assess departmental climate with help from outside experts and should respond, as needed, with educational workshops led by experts from student affairs or other resources.

1e. Professional societies should lead a coalition, similar to the Societies Consortium on Sexual Harassment in STEMM, to address identity-based harassment beyond sexual harassment.[26] Alternatively, members participating in the Societies Consortium should urge the existing body to broaden its efforts to include all forms of identity-based harassment including microaggressions and acts motivated by racism and bias.

FACTOR 2: PHYSICS IDENTITY

To persist, African American students must perceive themselves, and be perceived by others, as future physicists and astronomers.

Physics identity is defined as how one sees oneself with respect to physics as a profession, which evolves with one's perceptions and navigation of experiences with physics including recognition by others. African American students have to overcome stereotypes about who can become a physicist. How students perceive themselves with respect to physics is predictive of career intentions and achievement. As with belonging, the findings are a product of research by TEAM-UP and others. The recommendations provide departments with the means to create a strong sense of physics identity in all physics students.

Physics Identity: Key Findings

2a. Faculty encouragement and recognition are key enablers of physics identity for African American students. Physics identity development increases with the number of faculty who encourage and recognize student success.

2b. Participation in research, attendance and presentation at conferences, and working as a Learning Assistant all foster physics identity development.

2c. Faculty of the same race and ethnicity provide helpful role models whose support is especially meaningful to African American students.

2d. The connection of physics to activities that improve society or benefit one's community is especially important to African American students.

---

26 For more about the Societies Consortium, see http://educationcounsel.com/societiesconsortium/.

Physics Identity Recommendations

2a. Departments should invite speakers with demonstrated research expertise on physics identity development and should work with faculty on evidence-based ways to strengthen students' sense of physics identity, including encouragement and recognition.

2b. Departments should examine whether their current activities foster physics identity, assess their efficacy across race/ethnicity/gender and other social identities, and modify such activities as necessary.

2c. Departments should diversify their faculty with respect to race/ethnicity/gender and other social identities in such a way that support of underrepresented students is provided by multiple faculty of varying identities.

2d. Departments should communicate the ways in which a physics degree empowers graduates to improve society and benefit their communities, for example by inviting alumni to speak to students about these issues.

2e. Faculty should feature and discuss a broad range of career options with undergraduates, utilizing resources such as the AIP/SPS Careers Toolbox and the advice of African American alumni.

FACTOR 3: ACADEMIC SUPPORT

Effective teaching and a strengths-based approach to academic support are necessary for African American student retention and success.

Academic support is an obvious factor in student success. Too often, however, it is approached from the student deficit model—the idea that minoritized students have, as a consequence of their identity, learning challenges making them less capable than others. Combining deficit thinking with the problematic notion of meritocracy (McNamee 2018)—the idea that success is determined by ability, talent, and hard work—can lead to faulty judgment of students' potential. Site visits to the departments graduating the most African American students, as well as extensive research literature, show that the more effective approach recognizes student capabilities and builds on their strengths.

Academic Support: Key Findings

3a. Faculty who teach well and demonstrate commitment to students by affirming their academic abilities, encouraging their success, and helping them find additional resources are critically important in fostering student success.

3b. Overall student success increases with the number of committed and caring faculty in a department. It is important for faculty who are not members of marginalized groups to be engaged in these efforts to show students that they are valued.

3c. Advising systems that provide early warning of academic, financial, or other difficulties, and that intervene to reach students who may not seek help, are crucial for students to overcome challenges. These services may be provided by professional advisers collaborating with departments.

3d. Having multiple pathways into and through the major helps to recruit and retain students who may not have initially considered physics or astronomy as an option.

Academic Support: Recommendations

3a. Departments should encourage and support all new faculty to attend workshops on teaching and mentoring offered by their campus center for teaching and learning or other venues such as the New Faculty Workshop hosted by the American Association of Physics Teachers (AAPT) in conjunction with the American Astronomical Society (AAS) and APS.

3b. Departments should adopt policies and practices that encourage multiple faculty, including those who are not members of marginalized groups, to engage in formal and informal mentoring of students, and they should recognize and reward these efforts.

3c. Faculty and staff serving as undergraduate advisers should work closely with central advising offices to ensure that students facing academic, financial, and other difficulties can find the support they need.

3d. Departments should regularly and quantitatively assess their recruitment activities and curricular pathways, identify points at which students leave before graduation, and develop evidence-based, actionable plans to increase the persistence of all students to the degree.

3e. Departments should provide information about support services written in a manner accessible to and understandable by all students.

FACTOR 4: PERSONAL SUPPORT

Many African American students need support to offset financial burdens and stress.

Colleges and universities provide students with many kinds of support in addition to academic support. African American students often face challenges that require assistance from non-faculty experts, and awareness and referral by faculty can improve the students' utilization of resources. TEAM-UP research identified financial challenges as the greatest difficulty facing African American students compared with students of other racial and ethnic groups.

Personal Support: Key Findings

4a. Financial stress is particularly high for many African American students given the documented enormous racial wealth disparities in the US. Colleges and universities improve student retention and graduation by providing emergency support.

4b. Working on or off campus in a paid internship or a job related to their major, such as paid research, enables students to earn needed income while supporting academic progress.

4c. The need for mental health care is increased by financial and family stress (e.g., illness or death of a family member). Faculty and staff can normalize seeking help by discussing stress and self-care with students and referring them to campus resources.

4d. Student retention improves when faculty recognize students as individuals with unique and intersecting social identities and experiences, such as being a first-generation college student or working to support a family.

Personal Support: Recommendations

4a. Departments should identify campus resources for emergency financial aid, conference travel, and other unmet needs and help students take advantage of them.

4b. Faculty should seek funding for undergraduate students to work in research groups or as Learning Assistants, and find other ways to help students advance academically while earning money.

4c. Faculty and staff should normalize seeking help by discussing stress and self-care with students and referring them to campus resources.

4d. Faculty should strive to understand that students do not leave behind their identity and experiences when entering the classroom and should recognize the unique promise of each student from a perspective of strengths rather than weaknesses.

4e. A consortium of physical sciences societies should be formed to raise a $50M endowment from foundations and individuals to support minoritized students with unmet financial need in physics and astronomy and to support the implementation of this report's recommendations by departments. As an interim step, physics and astronomy societies should raise $1.2M per year to relieve the debt burden of African American bachelor's degree students.

FACTOR 5: LEADERSHIP AND STRUCTURES

For sustainability, academic and disciplinary leaders must prioritize creating environments, policies, and structures that maximize African American student success.

Effective departments create and sustain a supportive environment for all students. Department chairs play a key role in setting and acting on departmental priorities. Whether a department adopts the goal of increasing bachelor's degrees awarded to African American students, and what steps it takes to support that goal, are functions of the leadership. Effective academic leadership utilizes committees, existing decision-making bodies, internal funding and other resources, and coalition building to effect change. Sometimes a singularly dedicated faculty member, or a lone champion, creates a supportive environment for African American students. Evidence shows that such efforts are unsustainable.

Leadership and Structures: Key Findings

5a. Department chairs and officers can set norms and values; recruit, develop, and support faculty; and oversee structures, policies, and practices that enhance or diminish the success of African American students.

5b. Departmental initiatives can provide a scaffolding for student belonging, physics identity development, and academic support.

5c. Department connections to university- and college-level resources such as student affairs offices, dual-degree programs, research funding programs, multicultural centers, tutoring centers, etc., help to increase student awareness and usage of these valuable offerings.

5d. Lone champions can make a big difference for students, but their effort is unsustainable, making this an ineffective long-term strategy. In the most successful departments, a significant fraction of the faculty consistently value and support underrepresented students.

Leadership and Structures: Recommendations

5a. Department chairs and officers should set norms and values of inclusion and belonging; recruit, develop, and support a diverse faculty; and oversee structures, policies, and practices that enhance the success of African American students.

5b. Departments should identify, partner with, financially support, and advocate for campus programs like McNair Scholars that may already provide a scaffolding for student belonging, STEM identity development, and academic support of African American students.

5c. Departmental administrators should become familiar with and encourage students to utilize campus resources including student affairs offices, dual-degree programs, research funding programs, multicultural centers, tutoring centers, etc.

5d. Department chairs should provide incentives and rewards to multiple faculty members, including those who are not members of marginalized groups, who actively support underrepresented students.

5e. Professional societies should encourage existing and new groups within their organizations, such as the new APS Forum on Diversity and Inclusion, to examine ways to advance the recommendations of this and similar reports.

CHANGE MANAGEMENT

A new level of thinking is required to solve a persistent problem.

The underrepresentation of African Americans in physics is a systemic problem that cannot be solved through the work of individual faculty, departments, or professional societies. It requires coordinated efforts acting at all of these levels. In addition, standard approaches of strategic planning are unlikely to succeed because the underlying norms, values, and culture of the profession need to be addressed before lasting changes can occur. Fortunately, there is a growing body of literature on successful culture change in higher education to inform this work.

Professional societies have a leading role to play in this effort, as they did in the early 2000s with the SPIN-UP project to increase overall physics bachelor's degree production.

Change Management: Recommendations

6a. Professional societies and individual departments should each develop a theory of change utilizing sensemaking and shared leadership. The societies should hold discussion forums on this topic. Additionally, representatives from all groups should jointly produce a unified change management model highlighting the interactions among the societies, universities, departments, and individual physicists and astronomers needed to support their efforts.

6b. Departments should review and learn from related reports and programs of other science and scholarly organizations including the AAS (Nashville Recommendations, Diversity and Inclusion in Astronomy Graduate Education), APS (LGBT Climate in Physics, Effective Practices for Recruiting and Retaining Women in Physics, Effective Practices for Physics Programs, and the APS Inclusion, Diversity, and Equity Alliance), AAPT (New Faculty Programs), AAAS (SEA Change institutional awards and a parallel Physics and Astronomy SEA Change departmental award planned by disciplinary societies in the physical sciences), AAC&U (Project Kaleidoscope), and the National Academies of Science, Engineering, and Medicine (Sexual Harassment of Women, The Science of Effective Mentorship in STEMM).

6c. The professional societies should empower and prepare change agents by establishing and participating in faculty networks, learning communities, and skill-building workshops, including organizing sessions at their annual meetings to discuss this and related reports.

6d. The professional societies should establish or increase rewards and incentives for efforts by faculty members to improve the success of African American students (and other marginalized group members, who are not the focus of this report) in physics and astronomy.

6e. The professional societies and individual departments should gather relevant quantitative, qualitative, and descriptive data about their organizations, disaggregated by race/ethnicity/gender, as appropriate. Some organizational body, to be determined, should assess and publicly communicate progress toward the recommendations of this report every two to four years with both quantitative and qualitative data similar to those used in this report.

The TEAM-UP key findings and recommendations are outlined briefly for reference in Table 1, numbered as they were presented above. Each column is a theme area (the first five of which are the factors most responsible for success of African American students); each box below the top row gives a topic relevant to that theme.

Table 1: Key Findings and Recommendations by Theme

Belonging	Identity	Academic Support	Personal Support	Leadership and Structures	Change Management
Faculty role	Faculty role	Faculty preparation	Financial	Department chairs	Theory of change
Student role	Co-curriculum	Faculty commitment	Paid work	McNair and similar programs	Alignment with related efforts
Counterspaces	Faculty diversity	Advising	Mental health	Campus resources	Faculty preparation and training
Climate	Prosocial behaviors	Curriculum	Intersectional identity	Incentives and rewards	Rewards and incentives
Harassment response	Career options	Resource guide for students	$50M endowment for financial aid	Professional societies support	Ongoing data collection, assessment, and accountability

Items in **blue** cells describe **both key findings** and **recommendations**.

Items in **purple** cells describe **recommendations only**.

Glossary

AAAS: American Association for the Advancement of Science

AAC&U: American Association of Colleges and Universities

AAPT: American Association of Physics Teachers

AAS: American Astronomical Society

AIP: American Institute of Physics

APS: American Physical Society

Belonging (or sense of belonging, or belongingness): Having a feeling of being a welcome and contributing member of a community. Relevant communities for undergraduates within physics and astronomy include courses, teaching laboratories, departments, research laboratories, student clubs, professional societies, etc.

Black or African American: A category of race and ethnicity, or the name given to a minoritized identity group in the US. This report sometimes uses *Black* and *African American* interchangeably, although the latter category often is understood to exclude people of Caribbean descent or immigrants from other countries. We also follow the style guidelines of the American Psychological Association and always capitalize racial and ethnic categories including African American, Black, Asian, Hispanic, and White.

CERN: European Organization for Nuclear Research (in French, *Conseil Européen pour la Recherche Nucléaire*)

Cluster hiring: The practice of hiring multiple faculty members with a shared research interest and/or social identity for mutual support and collaboration. The faculty may be appointed in one or more departments.

Counterspace: Physical, virtual, or social safe space in which the needs, aspirations, social proclivities, and learning and communication styles of marginalized identity group members are centered and of paramount concern. These can include department or campus-wide clubs or organizations, mentoring networks, conferences, physical centers focused on particular marginalized groups, etc., and also outside groups such as churches and families.

CU^{2}MiP: Conference for Undergraduate Underrepresented Minorities in Physics. A pair of conferences designed to build community for minoritized students held in 2016 and 2017 at the University of Maryland, with the support of the National Institute of Standards and Technology.

Culture: The social behavior and norms found in human societies (from Wikipedia), as applied to organizations. Disciplinary cultural norms are often unspoken and assumed to be universally shared modes of interaction (for example, competitive versus cooperative styles of learning or conducting research).

First-generation student: A student whose parents or legal guardians have not completed a bachelor's degree.

Gender and gender binary: Most human societies assume all members can be accurately categorized as a member of one of two genders (gender binary) and that each member's gender identity can be accurately assigned at birth using primary sexual characteristics. Research in biology, psychology, and neuroscience and the lived experience of many people confirm that the gender binary, and assignment of gender identity at birth, are too limiting. Many people have gender identities at odds with the standard conflation of primary sexual characteristics with membership in one of two genders and may describe themselves as nonbinary. The data sources used for this report are based on the gender binary.

HBCUs: Historically Black Colleges and Universities, accredited by a nationally recognized accrediting agency or association (as defined by the Higher Education Act of 1965), whose principal mission was, and is, the education of Black Americans.

Identity-based harassment: Comments or actions that are designed to erode a group member's sense of belonging in a learning or professional community due to their membership in one or more marginalized identity groups. Harassment occurs by stating or implying that the target's membership in one or more marginalized identity group precludes them from acceptance and full participation in a learning or professional community.

Imposter phenomenon (or imposter syndrome): The belief that past accomplishments and demonstrations of skill and competence are attributed to luck rather than hard work and growing capabilities. For college students, this may manifest as a belief that they were the admissions office's sole mistake in choosing an entering class and that they are not capable of thriving in college. Students experiencing imposter phenomenon often think that their experience is unique, leaving them feeling isolated and eventually alienated from the learning community.

Intrusive advising: A style of advising in which the adviser does not assume that a student enters college with the self-advocacy skills and academic and social savvy to navigate college independently. The adviser "intrudes" to help students find the resources they need to become self-sufficient in planning their academic program, adjusting to academic setbacks, managing their finances and their time, using tutoring and other skill-building resources, forming study groups, finding research labs and internships, etc. Intrusive advising also involves intervention when students encounter financial hardship or other significant personal challenges.

IPEDS: Integrated Postsecondary Educational Data System, a portal for higher-education statistics provided by the National Center for Education Statistics of the US Department of Education.

Latinx: A person identifying as being of Latin American origin or descent, without specification of their gender identity, which can be binary or nonbinary.

LCURM: AIP Liaison Committee on Underrepresented Minorities (https://www.aip.org/member-benefits/liaison-committees/)

Learning Assistant (LA): An undergraduate student who, with the guidance of weekly preparation sessions and a pedagogy course, facilitates discussions among groups of students in a variety of classroom settings that encourage active engagement (https://www.colorado.edu/program/learningassistant/).

LHC: Large Hadron Collider, located at CERN

Marginalized identity groups: Groups of people defined by a common social identity who lack adequate social power or resources to design, build, or perpetuate social structures or institutions that reflect and reinforce the centrality and superiority of their identities, proclivities, and points of view. Members of marginalized groups must continually adjust their behavior in response to those with more social power. Members of marginalized groups are generally cognizant of the marginalized status of groups to which they belong. They need not be underrepresented or numerical minorities, but often are.

Microaggression: "The everyday verbal, nonverbal, and environmental slights, snubs, or insults, whether intentional or unintentional, which communicate hostile, derogatory, or negative messages to target persons based solely upon their marginalized group membership" (source: Derald Wing Sue, https://www.uua.org/sites/live-new.uua.org/files/microaggressions_by_derald_wing_sue_ph.d._.pdf). Members of marginalized identity groups are often subject to multiple and ongoing microaggressions that cumulatively can cause serious harm to the target's sense of belongingness in a community.

Minoritized identity groups: Marginalized identity groups that are also numerical minorities in a society but may be a majority in their environment (e.g., Hispanic-identifying children in Houston public schools). This report uses the term *minoritized* instead of *underrepresented minority* because social power and racial identity are not synonyms: minority status is conferred by the group with the most social power. The term *underrepresented students* is used to emphasize the numerical underrepresentation of a student group as opposed to its marginalization.

NASEM: National Academies of Science, Engineering, and Medicine

NCES: National Center for Education Statistics

NSBP: National Society of Black Physicists

PBI: Predominantly Black Institution. A college or university with at least 1,000 enrolled students, of whom at least 40% are Black or African American and at least 50% are low income or first generation to college.

PER: Physics Education Research

Physics identity: How one sees oneself with respect to physics as a profession, which evolves with one's perceptions and navigation of experiences with physics including recognition by others.

Prosocial behavior: A social behavior intended to benefit other people or society as a whole (Wikipedia).

PWI: Predominantly White institution

Qualitative research: A scientific method of observation to gather nonnumerical data. This type of research "refers to the meanings, concepts, definitions, characteristics, metaphors, symbols, and description of things" and not to their "counts or measures" (source: Wikipedia). This research answers why and how a certain phenomenon may occur rather than how often or to what extent.

Race and ethnicity: Socially constructed categories related to human ancestry. *Race* is defined as a category of humankind that shares certain distinctive physical traits. *Ethnicity* is more broadly defined as a classification of a large group of people according to common racial, national, tribal, religious, linguistic, or cultural origin or background. Race is usually associated with biology and linked with physical characteristics such as skin color or hair texture. Ethnicity is linked with cultural expression and identification. However, both are social constructs used to categorize and characterize seemingly distinct populations (source: Erin Blackmore, *National Geographic*).

Self-efficacy: Beliefs about one's ability to accomplish a task with skill and competence. Self-efficacy assumes the ability to advocate for oneself in order to collect the resources (pertinent information; new skills; social, physical, or financial capital, etc.) needed to accomplish a task.

Sensemaking: A learning process of creating meaning around concepts and ideas through a variety of social inputs including dialogue with others. Research in change processes in higher education suggests that culture change cannot happen without it.

Shared leadership: An arrangement in which power and decision-making authority are shared among top-level leaders (e.g., department chairs) and individuals with the most to gain from change but the least power to achieve it themselves (e.g., students, or faculty working on behalf of students). This model distributes leadership throughout an organization, providing multiple perspectives and internal accountability for outcomes.

Social identity: An individual's membership in groups that their society deems important in assigning social benefits, resources, and social status. Most individuals are members of both nonmarginalized and marginalized identity groups along different axes of identity. Social identity groups salient in our culture include those defined by race, ethnicity, gender, socioeconomic status, age, religion, sexual orientation, gender expression, physical ability, physical health, and mental health.

Social power: the ability to influence others or to control valued resources or outcomes among people.

SPS: Society of Physics Students, an organization of the American Institute of Physics

Stereotype threat: The debilitating cognitive load caused by fear that one's performance on a specific or extended task (e.g., an exam or whole course) could confirm a negative stereotype about an identity group to which one belongs. Stereotype threat manifests as anxiety and distraction that interfere with intellectual functioning. Members of historically underrepresented or marginalized groups can be particularly vulnerable to stereotype threat in academic settings, where their performance could confirm a negative stereotype about their group's intellectual capacity. Students are at highest risk for stereotype threat when they are working on challenging tasks at the edge of their knowledge and skills and care deeply about performing well—for instance, when taking difficult tests or engaging in complicated classroom discussions, potentially on sensitive or identity-relevant topics. The anxiety associated with stereotype threat can interfere with intellectual functioning not only in the classroom but throughout campus life.

Stop out: To take a break for one or more terms of college or university with the intention of returning.

Student deficit model: A framework that rests on the assumption that minoritized students have learning challenges or needs, and that if they work harder to bridge those gaps they can achieve greater success.

Theory of change: A comprehensive description and illustration of how and why a desired change is expected to happen in a particular context (https://www.theoryofchange.org/what-is-theory-of-change/).

References

Agüeros, A., Basri, G., Bertschinger, E., Coble, K., Donahue, M., Monkiewicz, J., Rudolph, A., Speck, A., Stassun, K., Ivie, R., Pfund, C., & Posselt, J. (2019). Final Report of the 2018 AAS Task Force on Diversity and Inclusion in Astronomy Graduate Education. *Bulletin of the American Astronomical Society, 51*, 1–74. (https://aas.org/education/aas-task-force-diversity-and-inclusion-graduate-astronomy-education)

Arroyo, A. T., & Gasman, M. (2014). An HBCU-Based Educational Approach for Black College Student Success: Toward a Framework with Implications for All Institutions. *American Journal of Education*, *121*(1), 57–85. (https://doi.org/10.1086/678112)

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is Science Me? High School Students' Identities, Participation and Aspirations in Science, Engineering, and Medicine. *Journal of Research in Science Teaching*, *47*(5), 564–582. (https://doi.org/10.1002/tea.20353)

Atherton, T. J., Barthelemy, R. S., Deconinck, W., Falk, M. L., Garmon, S., Long, E., Plisch, M., Simmons, E. H., & Reeves. K. (2016). *LGBT Climate in Physics: Building an Inclusive Communit*y. College Park, MD: American Physical Society. (https://www.aps.org/programs/lgbt/)

Avila, M. (2010). Community Organizing Practices in Academia: A Model, and Stories of Partnerships. *Journal of Higher Education Outreach and Engagement*, *14*(2), 37–64. (http://openjournals.libs.uga.edu/index.php/jheoe/article/view/43/38)

Baum, S. (2019). *Rethinking Federal Work-Study: Incremental Reform Is Not Enough*. Washington, DC: Urban Institute. (https://www.urban.org/research/publication/rethinking-federal-work-study-incremental-reform-not-enough)

Bricker, J., Dettling, L. J., Henriques, A., Hsu, J. W., Jacobs, L., Moore, K. B.,… Windle, R. A. (2017). Changes in U.S. Family Finances from 2013 to 2016: Evidence from the Survey of Consumer Finances. *Federal Reserve Bulletin, 103*(3), 1–42.

(https://www.federalreserve.gov/publications/2017-September-changes-in-us-family-finances-from-2013-to-2016.htm)

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What Kind of a Girl Does Science? The Construction of School Science Identities. *Journal of Research in Science Teaching*, *37*(5), 441–458.

Carlone, H. B., & Johnson, A. (2007). Understanding the Science Experiences of Successful Women of Color: Science Identity as an Analytic Lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218. (https://doi.org/10.1002/tea.20237)

Center for Responsible Lending (2019). *Quicksand: Borrowers of Color and the Student Debt Crisis*. Report issued by CRL in collaboration with the National Association for the Advancement of Colored People, UnidosUS, the National Urban League, and the Leadership Conference on Civil and Human Rights. (https://www.responsiblelending.org/research-publication/quicksand-borrowers-color-student-debt-crisis)

Clancy, K. B. H., Lee, K. M. N., Rodgers, E. M., & Richey, C. (2017). Double Jeopardy in Astronomy and Planetary Science: Women of Color Face Greater Risks of Gendered and Racial Harassment. *Journal of Geophysical Research: Planets*, *122*, 1610–1623. (https://doi.org/10.1002/2017JE005256)

Close, E. W., Conn, J., & Close, H. G. (2016). Becoming Physics People: Development of Integrated Physics Identity Through the Learning Assistant Experience. *Phys. Rev. Phys. Educ. Res.*, *12*, 010109. (https://doi.org/10.1103/PhysRevPhysEducRes.12.010109)

Cox, M. D., & Richlin, L., eds. (2004). Building Faculty Learning Communities: New Directions for Teaching and Learning. *New Directions for Teaching & Learning, 97*, 1–157. (https://onlinelibrary.wiley.com/toc/15360768/2004/2004/97)

Crenshaw, K. (1989). Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics. *University of Chicago Legal Forum*, *vol. 1989*, 139–168.

Dobbin, F., & Kalev, A. (2016). Why Diversity Programs Fail. *Harvard Business Review*, July/August 2016 issue, 52–60. (https://hbr.org/2016/07/why-diversity-programs-fail)

Elrod, S., & Kezar, A. (2016). *Increasing Student Success in STEM.* Washington, DC: Association of American Colleges and Universities. (https://www.aacu.org/publications-research/publications/increasing-student-success-stem-guide-systemic-institutional)

Elrod, S., & Kezar, A. (2017). Increasing Student Success in STEM: Summary of a Guide to Systemic Institutional Change. *Change: The Magazine of Higher Learning*, *49*(4), 26–34. (https://doi.org/10.1080/00091383.2017.1357097)

Espinosa, L. L., Turk, J. M., Taylor, M., & Chessman, H. M. (2019). *Race and Ethnicity in Higher Education: A Status Report*. Washington, DC: American Council on Education. (https://www.equityinhighered.org/resources/report-downloads/)

Feder, T. (2019). NAS Adopts Policy to Expel Sexual Harassers. *Physics Today, 11 June 2019* in *Politics and Policy*. (https://doi.org/10.1063/PT.6.2.20190611a)

Fries-Britt, S., Cabrera, A., Kurban, E., & McGuire, D. (2019, Manuscript under review). A Nuanced Understanding of Minority Students' Intentions and Commitment to STEM.

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The Science Identity of College Students: Exploring the Intersection of Gender, Race, and Ethnicity. *Journal of College Science Teaching*, *42*(5), 82–91. (https://www.jstor.org/stable/43631586)

Hilborn, R. C., Howes, R. H., & Krane, K. S. (2003). *Strategic Programs for Innovations in Undergraduate Physics: Project Report.* College Park, MD: American Association of Physics Teachers. (https://www.aapt.org/Programs/projects/spinup/upload/SPIN-UP-Final-Report.pdf)

Hilborn, R. C. (2012). What Works for Thriving Undergraduate Physics Programs, Paper presented at *Texas SPIN-UP Workshop, May 4–6, 2012*, Austin, TX. (https://www.aapt.org/Programs/projects/spinup/upload/hilborn.pdf)

Hyater-Adams, S., Fracchiolla, C., Finkelstein, N., & Hinko, K. (2018). Critical Look at Physics Identity: An Operationalized Framework for Examining Race and Physics Identity. *Phys. Rev. Phys. Educ. Res.*, *14*, 010132. (https://doi.org/10.1103/PhysRevPhysEducRes.14.010132)

Hyater-Adams, S., Fracchiolla, C., Williams, T., Finkelstein, N., & Hinko, K. (2019). Deconstructing Black physics identity: Linking individual and social constructs using the critical physics identity framework. *Phys. Rev. Phys. Educ. Res.*, *15*, 020115. (https://doi.org/10.1103/PhysRevPhysEducRes.15.020115)

Jerome, F., & Taylor, R. (2005). *Einstein on Race and Racism*. New Brunswick, NJ: Rutgers University Press.

Johnson, A., Ong, M., Ko, L. T., Smith, J., & Hodari, A. (2017). Common Challenges Faced by Women of Color in Physics, and Actions Faculty Can Take to Minimize Those Challenges. *The Physics Teacher*, *55*, 356–360. (https://doi.org/10.1119/1.4999731)

Johnson, I. R., Pietri, E. S., Fullilove, F., & Mowrer, S. (2019). Exploring Identity-Safety Cues and Allyship Among Black Women Students in STEM Environments. *Psychology of Women Quarterly*, *43*(2), 131–150. (https://doi.org/10.1177/0361684319830926)

Kezar, A. (2014). *How Colleges Change: Understanding, Leading, and Enacting Change*. New York: Routledge Press.

Kezar, A., & Holcombe, E. (2017). *Shared Leadership in Higher Education: Important Lessons from Research and Practice*. Washington, DC: American Council on Education. (https://www.acenet.edu/Documents/Shared-Leadership-in-Higher-Education.pdf)

Kezar, A., & Maxey, D. (2014). Faculty Matter: So Why Doesn't Everyone Think So? Thought and Action, *Thought & Action*, *issue Fall 2014*, 29–44. (http://www.nea.org/assets/docs/HE/e-Kezar.pdf)

Lau, A., Dancy, M., Corbo, J., Henderson, C., & Rundquist, A. (2017). An Analysis of Community Formation in Faculty Online Learning Communities. Paper presented at *Physics Education Research Conference 2017*, Cincinnati, OH, 232–235. (https://doi.org/10.1119/perc.2017.pr.053)

Lumina Foundation (2018). *Beyond Financial Aid*. Indianapolis, IN: Lumina Foundation. (https://www.luminafoundation.org/resources/beyond-financial-aid)

McNamee, Stephen (2018). *The Meritocratic Myth,* 4th edition. Lanham, MD: Rowman & Littlefield.

Merner, L., & Tyler, J. (2019). African-American Participation Among Bachelors in the Physical Sciences and Engineering. *Focus On report of the American Institute of Physics Statistical Research Center, August 2019*. College Park, MD: American Institute of Physics. (https://www.aip.org/statistics/reports/african-american-participation-among-bachelors-physical-sciences)

Monsalve, C., Hazari, Z., McPadden, D., Sonnert, G., & Sadler, P. M. (2016). Examining the Relationship Between Career Outcome Expectations and Physics Identity. Paper presented at *Physics Education Research Conference 2016*, Sacramento, CA, 228–231. (https://doi.org/10.1119/perc.2016.pr.052)

Morsy, L., & Rothstein, R. (2016). *Mass Incarceration and Children's Outcomes: Criminal Justice Policy Is Education Policy*, Economic Policy Institute Report 118615, December 15, 2016. (http://www.epi.org/publication/mass-incarceration-and-childrens-outcomes/)

NAS (National Academy of Science) (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*. Washington, DC: The National Academies Press. (https://doi.org/10.17226/21739)

NASEM (National Academies of Science, Engineering, and Medicine) (2018a). *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine*. Washington, DC: The National Academies Press. (https://doi.org/10.17226/24994)

NASEM (2018b). *Graduate STEM Education for the 21st Century*. Washington, DC: The National Academies Press. (https://doi.org/10.17226/25038)

NASEM (2019). *The Science of Effective Mentorship in STEMM*. Washington, DC: The National Academies Press. (https://doi.org/10.17226/25568)

Nicholson, S., & Mulvey, P. J. (2019). Roster of Physics Departments with Enrollment and Degree Data, 2018. American Institute of Physics Statistical Research Center, October 2019. College Park, MD: American Institute of Physics. (https://www.aip.org/statistics/reports/roster-physics-2018)

Nissen, J. M., & Shemwell, J. T. (2016). Gender, Experience, and Self-Efficacy in Introductory Physics. *Phys. Rev. Phys. Educ. Res.*, *12*, 020105. (https://doi.org/10.1103/PhysRevPhysEducRes.12.020105)

Ong, M., Smith, J. M., & Ko, L. T. (2017). Counterspaces for Women of Color in STEM Higher Education: Marginal and Central Spaces for Persistence and Success. *Journal of Research in Science Teaching*, *55*(2), 206–245. (https://doi.org/10.1002/tea.21417)

Oyserman, D. (2015). Identity-Based Motivation. In *Emerging Trends in the Social and Behavioral Sciences*, ed. R. A. Scott and S. M. Kosslyn. Hoboken, NJ: John Wiley and Sons. (https://doi.org/10.1002/9781118900772.etrds0171)

Packard, B. W.-L. (2016*). Successful STEM Mentoring Initiatives for Underrepresented Students: A Research-Based Guide for Faculty and Administrators*. Sterling, VA: Stylus Publishing.

Quan, G. M., Corbo, J. C., Finkelstein, N. D., Pawlak, A., Falkenberg, K., Geanious, C., Ngai, C., Smith, C., Wise, S., Pilgrim, M. E., & Reinholz, D. L. (2018). Designing for Institutional Transformation: Six Principles for Department-Level Interventions. *Phys. Rev. Phys. Educ. Res.*, *15*, 010141. (https://doi.org/10.1103/PhysRevPhysEducRes.15.010141)

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and Gender Differences in How Sense of Belonging Influences Decisions to Major in STEM. *International Journal of STEM Education*, *5*, 10. (https://doi.org/10.1186/s40594-018-0115-6)

Riegle-Crumb, C., King, B., & Irizarry, Y. (2019). Does STEM Stand Out? Examining Racial/Ethnic Gaps in Persistence Across Postsecondary Fields. *Educational Researcher, 48*(4), 244–244. (https://doi.org/10.3102/0013189X19849410)

Sabella, M. S., Mardis, K., Sanders, N., & Little, A. (2017). The Chi-Sci Scholars Program: Developing Community and Challenging Racially Inequitable Measures of Success at a Minority-Serving Institution on Chicago's Southside. *The Physics Teacher, 55*, 350–355. (https://doi.org/10.1119/1.4999730)

Schexnider, A. J. (2017). Governance and the Future of Black Colleges. *Inside Higher Ed.*, December 20, 2017. (https://www.insidehighered.com/views/2017/12/20/struggling-hbcus-must-consider-new-options-survival-opinion)

Scott-Clayton, J., & Zhou, R. Y. (2017). *Does the Federal Work-Study Program Really Work—and for Whom?* New York: Columbia University, Teachers College, Center for Analysis of Postsecondary Education and Employment. (https://ccrc.tc.columbia.edu/media/k2/attachments/capsee-does-fws-program-really-work.pdf)

Steele, C. (2011). *Whistling Vivaldi: How Stereotypes Affect Us and What We Can Do*. New York: W. W. Norton and Company.

Steve Fund and Jed Foundation (2017). *Equity in Mental Health Framework*. (https://equityinmentalhealth.org/framework/)

Sue, D. W. (2010). *Microaggressions in Everyday Life*. Hoboken, NJ: John Wiley and Sons.

Traweek, S. (1988). *Beamtimes and Lifetimes: The World of High-Energy Physicists*. Cambridge, MA: Harvard University Press.

Trujillo, G., & Tanner, K. D. (2014). Considering the Role of Affect in Learning: Monitoring Students' Self-Efficacy, Sense of Belonging, and Science Identity. *CBE Life Sci. Educ.*, *13*(1), 6–15. (https://doi.org/10.1187/cbe.13-12-0241)

Vinkenburg, C. J. (2017). Engaging Gatekeepers, Optimizing Decision Making, and Mitigating Bias: Design Specifications for Systemic Diversity Interventions. *The Journal of Applied Behavioral Science*, *53*(2), 212–234. (https://doi.org/10.1177/0021886317703292)

Wang, J., & Hazari, Z. (2018). Promoting High School Students' Physics Identity Through Explicit and Implicit Recognition. *Phys. Rev. Phys. Educ. Res.*, *14*, 020111. (https://doi.org/10.1103/PhysRevPhysEducRes.14.020111)

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity (Learning in Doing: Social, Cognitive and Computational Perspectives)*. Cambridge, UK: Cambridge University Press.

White, S., & Tyler, J. (2015). Underrepresented Minorities in High School Physics: Results from the 2012–13 Nationwide Survey of High School Physics Teachers. *Focus On report of the American Institute of Physics Statistical Research Center, June 2015*. College Park, MD: American Institute of Physics. (https://www.aip.org/sites/default/files/statistics/highschool/hs-underrepmin-13.pdf)

Williams, K. L., & Davis, B. L. (2019). *Public and Private Investments and Divestments in Historically Black Colleges and Universities*. Washington, DC: American Council on Education. (Issue Brief, https://www.acenet.edu/news-room/Documents/public-and-private-investments-and-divestments-in-hbcus.pdf)

Williams, Q. (2010). Undergraduate Physics Programs at HBCUs: Can We Stop the Losses? *Physics Today*, *63*(6), 47–48. (https://doi.org/10.1063/1.3455321)

AIP Task Force Chairs

Mary James

Physics Professor and Dean of Institutional Diversity, Reed College, Dr. James has served as both a member and chair of the APS Committee on Minorities in physics for two years and was instrumental in launching the APS National Mentoring Community. She has vast experience with diversity and committee/task group dynamics.

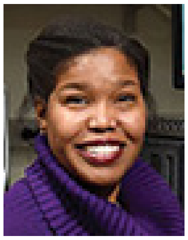
Edmund Bertschinger

Edmund Bertschinger is a Professor of Physics at MIT with an affiliation in the Program in Women's and Gender Studies. He is a scholar-activist-administrator for diversity, equity, and inclusion in higher education. Dr. Bertschinger has served as both Physics Department Head and MIT's inaugural Community and Equity Officer. He is passionate about shifting the culture of STEM fields to be inclusive and equitable for everyone.

Task Force Members

Brian Beckford

Brian Beckford is currently an assistant research scientist following a two-year President's Postdoctoral Fellowship (PPFP) at the University of Michigan, where he served as the former chair of the physics department's Diversity, Equity, and Inclusion committee. He works on the KOTO experiment, conducted at the J-PARC facility in Japan, which is designed to measure the rare CP-violating decay of a neutral long-lived kaon into a neutral pion and a neutrino anti-neutrino pair. Prior to his position at Michigan, Dr. Beckford was the American Physical Society (APS) Bridge Program Manager, overseeing that multimillion dollar program to increase the production of African Americans earning PhDs in physics.



Tabbetha Dobbins

Associate Professor of Physics at Rowan University and strong promoter of diversity in physics at the undergraduate level, Dr. Dobbins earned her degrees at both HBCUs (Lincoln U.) and Predominantly White Institutions (U. Penn and Penn State). Following these experiences, she returned to her HBCU roots as a faculty member at Grambling University, and simultaneously held a position at Louisiana Tech, before landing at Rowan. She is fiercely dedicated to her undergraduate students and participates in diversity panels around the country.

Sharon Fries-Britt

Sharon Fries-Britt is a Professor of Higher Education, at the University of Maryland in the Department of Counseling, Higher Education and Special Education (CHSE). She studies the experiences of high achieving Blacks in higher education and underrepresented minorities (URMs) in STEM fields. Her recent work examines within group experiences of native and non-native Blacks in higher education as well as issues of campus racial climate. Dr. Fries-Britt is one of the faculty co-leads and authors of the ACE report Speaking Truth and Acting With Integrity Confronting Challenges of Campus Racial Climate. Dr. Fries-Britt's research has been funded and supported by the Lumina Foundation, National Society of Black Physicists and the National Science Foundation where she is co-principle investigator to examine the academic trajectories of Black transfer engineering students from community colleges. A recipient of numerous awards she was named a 2019-2020 University of Maryland Distinguished Scholar Teacher.

Sylvester James Gates

A world-renowned theoretical physicist, Dr. Gates is the Brown Theoretical Physics Center Director and Ford Foundation Physics Professor at Brown University. This follows his appointment as the John S. Toll professor of physics at the University of Maryland, College Park. He has served on national committees including the U.S. Presidential Council of Advisors on Science & Technology (PCAST) and the National Commission on Forensic Science. Throughout his career, he has been an outspoken national advocate for diversity in physics and was cited regarding an amicus brief to the Supreme Court on the value of minorities in physics. Currently Dr. Gates is a Fellow and vice-President of the American Physical Society (APS) also a Fellow and Past-President of the National Society of Black Physicists (NSBP).

Jedidah Isler

Jedidah Isler is currently an Assistant Professor of Physics & Astronomy at Dartmouth College. Dr. Isler was formerly an NSF Postdoctoral Fellow at Vanderbilt University and was the first African American woman to receive a PhD in astrophysics from Yale University. She is an award-winning astrophysicist, TED Fellow, and a nationally recognized speaker and advocate for inclusive STEM education. Dr. Isler is also the creator and host of the monthly web series "Vanguard: Conversation with Women of Color in STEM."

Maria Ong

Maria (Mia) Ong, Ph.D., is a Senior Research Scientist at TERC, a science and mathematics education non-profit organization in Cambridge, MA. For over twenty years, she has conducted empirical research focusing on women of color in higher education and careers in STEM and has led the evaluation of several STEM equity and inclusion programs. She specializes in qualitative methods, gender and race/ethnicity issues in STEM, and higher education. Dr. Ong is a former member of the National Science Foundation's Committee on Equal Opportunities in Science and Engineering, a Congressionally mandated advisory committee, and she currently serves on the National Academies Committee on Addressing the Underrepresentation of Women of Color in Tech. Prior to her work at TERC, she directed an undergraduate physics program for students of color and women at the University of California at Berkeley; for this work, she co-received a U.S. Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring. Dr. Ong holds a doctorate in Social and Cultural Studies in Education from U.C. Berkeley.

Arlisa Richardson

Currently a faculty member in the physics department at Chandler-Gilbert Community College, Dr. Richardson has had a rich and varied career. She received her physics bachelor's degree at Grambling State (HBCU), her physics Master's degree at UT Dallas, a second Master's degree in materials & engineering, and a PhD in science curriculum, both from the University of Arizona. Dr. Richardson also spent a significant amount of time working as an engineer in private industry before returning to academia. In that time, she has worked with diversity organizations to increase access to science for underrepresented minorities and she is now running as a candidate for the AAPT Board of Directors

Quinton Williams

Professor and chair of physics at Howard University, Dr. Williams has a history of leadership in APS, AAPT and AIP diversity efforts. As a former Provost at Jackson State and current physics chair at Howard, he is a staunch advocate for the health and well-being of HBCUs and for their recognition as the leading producers of African American physics bachelor's degrees. Dr. Williams is a former member of the AIP Governing Board and was a member of the APS and AAPT Joint Task Force on Undergraduate Physics Programs, which recently released their report, Physics 21: Preparing physics students for 21st century careers. Quinton is also a Past-President of the National Society of Black Physicists (NSBP).

AIP Project Staff

Arlene Modeste Knowles

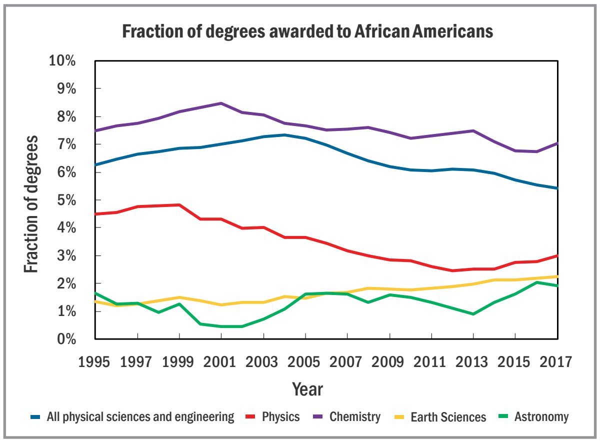
Arlene Modeste Knowles is the American Institute of Physics TEAM UP Project Manager. Ms. Knowles selected and convened the TEAM-UP members to execute their charge and complete this project. Additionally, Ms Knowles co-led initial efforts on the development of the SEA Change Physics and Astronomy Departmental Awards and is the 2020 Chair of the American Association of Physics Teachers Committee on Diversity in Physics (CoDP). Formerly, Ms. Knowles spent more than two decades managing and coordinating diversity programs for the American Physical Society including the now retired, Scholarships for Minority Undergraduate Physics Majors, and the National Mentoring Community, a mentoring program to increase the number of minority physics bachelor's degrees. She advocated for the creation of the APS ad-hoc Committee on LGBT+ issues and worked with them to elevate the presence of LGBT+ physicists within the APS community and produce the first ever, LGBT Climate in Physics Report. Ms. Knowles also served on the Program Management Team of the multi-million dollar grant-funded, APS Bridge Program, and has been instrumental in establishing and advancing several APS diversity initiatives.

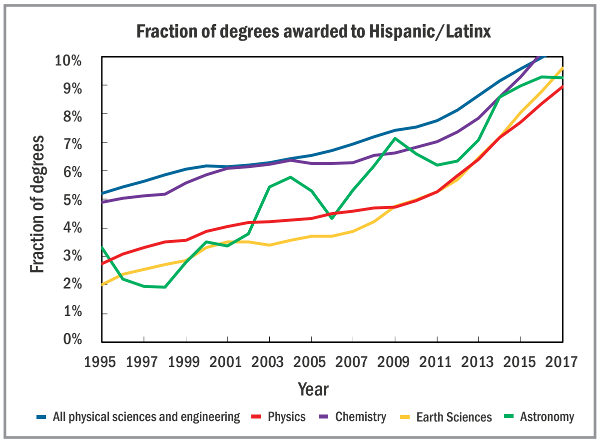
Philip W. "Bo" Hammer

Bo Hammer is a Senior Director at the American Institute of Physics (AIP) and the Staff Liaison to the AIP Liaison Committee on Underrepresented Minorities (LCURM). Dr. Hammer, in partnership with LCURM, wrote the proposal to the AIP Board to authorize and fund a national Task Force on the underrepresentation of African Americans in physics & astronomy. Prior to assuming his role at AIP, Dr. Hammer was Associate Executive Officer of the American Association of Physics Teachers and a Vice President at the Franklin Institute Science Museum. Dr. Hammer was an American Physical Society Congressional Science Fellow in the US House of Representatives Committee on Science, and currently serves on the advisory committee for the AAAS Leshner Leadership Institute. He has served on the Executive Board and Council of the APS and was a founder of the APS Forum on Physics and Society. Dr. Hammer is a Fellow of the American Physical Society.

APPENDIX 1: DEMOGRAPHIC DATA FOR PHYSICS AND ASTRONOMY

The rationale for the formation of this task force is that, over the past two decades, the percentage of physics bachelor's degrees awarded to African Americans has declined, in contrast with several other disciplines in the physical sciences. The percentage of astronomy bachelor's degrees awarded to African Americans is smaller but has remained steady and has not declined. By contrast, the percentages of degrees awarded to Hispanic/ Latinx students has grown significantly. The trends are shown in Figures 1 and 2.[1]





Figures 1 & 2: Bachelor's degree trends. Curves have been averaged over three years to reduce variability due to small numbers
Source: IPEDS

An obvious question is why the trends are so different for African Americans and Hispanic Americans. One possibility is overall population trends. The Hispanic population is the fastest-growing major race/ethnicity group in the US. During the 20-year period between 1997 and 2017, the fraction of college-age Americans who are African American remained relatively steady, at 14% to 15%. During the same period, the fraction who are Hispanic grew from 16% to 22%.

But overall population growth does not tell the whole story. There are additional factors at play, some of which can be gleaned from quantitative data. The first factor is the percentage of 18- to 24-year-olds who enroll in college. In 2017 this fraction was the same for Black and Hispanic Americans, 36% (compared with 41% for Whites). However, colleges include both two-year and four-year institutions, and Hispanic Americans attend two-year colleges at higher rates than other groups.[2] As a consequence, in 2017, 13% of enrolled students at four-year colleges and universities were Black and 16% were Hispanic; at two-year colleges the fractions were 14% and 26%, respectively. But enrollments in four-year colleges and universities do not tell the whole story either. The fraction of students who select physics or astronomy as a major, the fraction who switch into or out of physics, and the fraction who persist to a degree, all depend on race, ethnicity, gender, and other variables.

---

[1] Data are from the National Center for Education Statistics (NCES) Integrated Postsecondary Educational Data System (IPEDS). In 2010 the racial/ethnic categories were changed to allow people to select two or more races, resulting in some undercounting of African Americans and other multiracial students. We have not corrected for this change.

[2] Data in this paragraph come from the NCES *Digest of Education Statistics*, Tables 101.20 (population) and 302.60 and 306.20 (enrollments); see https://nces.ed.gov/programs/digest/current_tables.asp (last accessed on August 18, 2019).

Ignoring the complications, one can ask whether the racial and ethnic distribution of physics bachelor's degrees matches that of four-year college enrollments. It does not. Instead of 13% and 16% for Black and Hispanic students (the overall four-year college enrollment fractions in 2017), the fractions for physics bachelor's degrees are 3% and 9%, respectively. Clearly, a smaller fraction of enrolled African American students than Hispanic American students are obtaining physics degrees. To achieve parity, as measured by four-year enrollments, would require increases by a factor of 4.4 for African Americans and 1.8 for Hispanic Americans. A more realistic analysis would consider degrees awarded rather than enrollments. In this case the factors are 3.1 for African Americans and 1.5 for Hispanic Americans.

What is important to take from this analysis is that African American college students are significantly less likely to obtain a physics bachelor's degree than Hispanic students, who are members of a comparably large (indeed, now somewhat larger) underrepresented minoritized group.

These numbers cannot tell us *why* African Americans are less likely than others to obtain physics or astronomy bachelor's degrees. Clues can be found from additional data. One clue comes from comparing different academic fields.

The number of bachelor's degrees awarded in physics in the US is at an all-time high (AIP counts 8,946 degrees in 2018; Nicholson and Mulvey 2018). Across all fields, the percentage of bachelor's degrees awarded to African Americans has more than doubled since 1995 (Figure 2 in the Introduction). If this were true in physics, the TEAM-UP task force might not have been convened. Comparing degrees awarded across all fields, physical sciences and engineering, and physics, Table 1 shows that between 1995 and 2017 physics has shown the *largest decrease* for African Americans (and *largest growth* for Hispanic Americans) across several fields based on ratios of 2016–2017 to 1994–1995 data.[3] Table 2 (Merner and Tyler 2019) amplifies the point. In order to not lose ground, physics would have to double the number of bachelor's degrees awarded to African Americans.

	Black or African American			Hispanic		
	1994–1995	2016–2017	Ratio	1994–1995	2016–2017	Ratio
All Fields	7.3%	9.2%	1.27	5.7%	13.1%	2.31
Physical Sciences and Engineering[4]	6.3%	5.3%	0.85	5.2%	10.3%	1.97
Physics	4.5%	3.0%	0.66	2.7%	8.8%	3.23

Table 1: Bachelor's degree statistics from IPEDS

[3] Among the 11 largest fields of mathematics, physical sciences, and engineering, only math showed a greater decrease than physics for African Americans and only earth sciences showed a greater increase for Hispanic Americans.

[4] The largest disciplines in this category, in decreasing order of numbers of bachelor's degrees awarded in 2016–2017, are: computer science, mechanical engineering, mathematics, electrical engineering, chemistry, civil engineering, chemical engineering, computer engineering, physics, biomedical engineering, and earth sciences.

Number of Bachelor's Degrees Earned by African-Americans in Physical Science Fields, 2005 and 2015

	Total Number of Degrees Earned by All Students		Number of Degrees Earned by African Americans	
	Degrees in 2015	Percent Change 2005 to 2015	Degrees in 2015	Percent Change 2005 to 2015
Earth Sciences	6,387	94%	146	165%
Atmospheric Sciences	740	9%	14	75%
Chemistry	15,567	46%	1,036	31%
Physics	7,329	57%	175	4%
Astronomy	480	25%	10	67%
Oceanography	265	91%	9	29%
Other Physical Sciences	759	32%	62	72%
All Physical Sciences	31,527	55%	1,452	36%

AIP | American Institute of Physics   aip.org/statistics

Table 2: Comparison of bachelor's degrees awarded in physical science, 2005 and 2015.

Tables 1 and 2 expand the point made by Figures 1 and 2. Physics is doing relatively well in graduating Hispanic Americans but not African Americans. Across the physical sciences, physics has shown the least progress, notwithstanding the major efforts to strengthen physics undergraduate programs following the SPIN-UP report (Hilborn, Howes, and Krane 2003).

Fields with very little diversity in 1997, such as astronomy and earth sciences, are catching up to physics (Figures 1 & 2). Even so, the percentage of astronomy bachelor's degrees awarded to African Americans remains very small, just 1.9% in 2016–2017. Similar to physics, astronomy has shown strong increases for Hispanic Americans, who received 9.3% of astronomy bachelor's degrees in 2016–2017. However, astronomy also has a problem attracting and graduating Black undergraduates.

More clues are needed to explain the circumstances of African Americans in physics. Another important clue comes from examining which colleges and universities award the most bachelor's degrees to African Americans. Table 3 shows the top 12 producers for the five-year period ending June 30, 2017.

College or University	Physics Bachelor's Degrees Awarded to African Americans, 2012–2017
Morehouse College	32
Alabama A&M University	20
Dillard University	19
Xavier University of Louisiana	18
Hampton University	17
Howard University	15
Jackson State University	15
North Carolina A&T University	15
Tuskegee University	15
Florida A&M University	14
Georgia State University	14
Benedict College	13

Table 3: Top 12 producers of physics bachelor's degrees awarded to African Americans, July 1, 2012, through June 30, 2017. Numbers exclude international students, multiracial students, and those of unknown race/ethnicity; they also exclude engineering physics. (Source: IPEDS.)

Of the 12 institutions in Table 3, all are HBCUs except Georgia State, which is a PBI (Predominantly Black Institution, defined in the Glossary). Of the 33 HBCUs with physics programs, 29 awarded at least one physics bachelor's degree during the five-year period stated. During the same period, 4 PBIs produced at least one physics bachelor's degree: Georgia State University, Chicago State University, Francis Marion University, and CUNY York College. No HBCU or PBI has an astronomy bachelor's degree program.

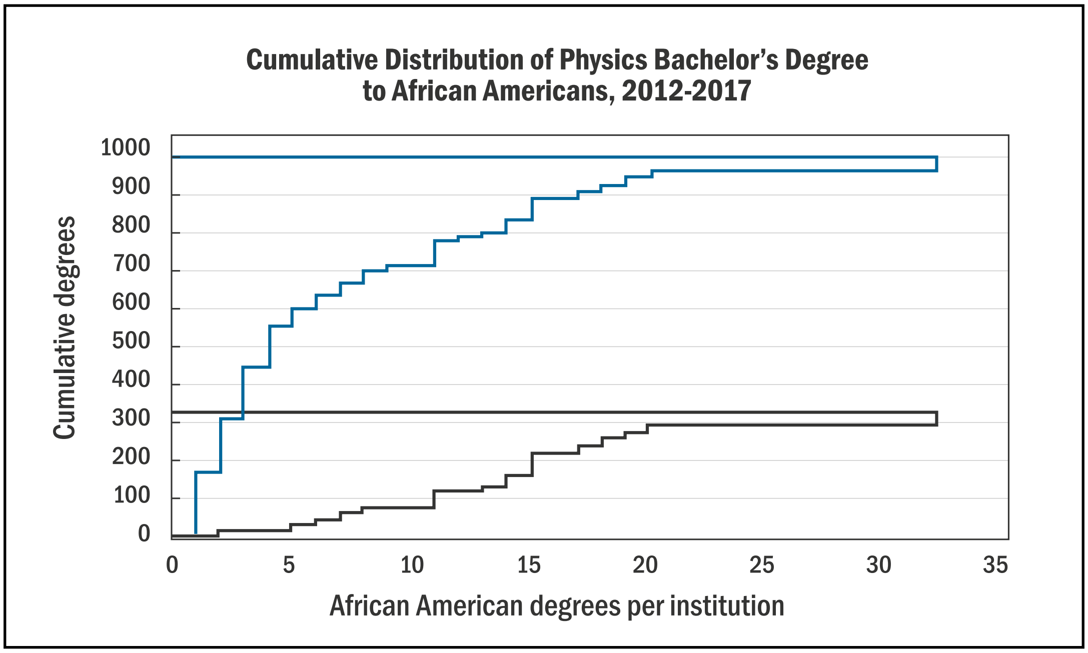


Figure 3: HBCUs and PBIs disproportionately produce African American physics bachelors, however two-thirds of African American physics bachelor's degrees were earned at PWIs in the period from 2012-2017. Morehouse College was responsible for 3% of the total African American physics bachelor's degrees in this period.

Source: IPEDs

Although HBCUs dominate the high end of degree producers for African Americans, they produce only about 30% of all physics degrees awarded to African Americans at present. Figure 3 shows the cumulative distribution using data for the five-year period July 1, 2012, through June 30, 2017. Of the 774 departments that awarded physics bachelor's degrees during this period, only 357 awarded one or more degrees to African Americans. Each point on the top curve gives the total number of degrees awarded by departments that awarded fewer than N degrees, where N is the horizontal axis value. A total of 997 physics bachelor's degrees were awarded to African American students; 170 of these were in departments that awarded only one degree in five years. At the other end of the scale, 32 degrees were awarded by Morehouse College and 20 degrees were awarded by the next-most-productive university, Alabama A&M University.

The top curve in Figure 3, in blue, includes all physics departments. The bottom curve, in black, shows only the degrees awarded at HBCUs and PBIs. For $N > 12$, the two curves match (but are vertically offset), because no PWI (Predominantly White Institution) awarded more than 12 degrees. (MIT awarded 12 degrees to African Americans.) Only 46% of all physics departments (that produced any degrees at all) produced any degrees to African Americans during the selected time period. Excluding departments that produced zero degrees in five years, the median PWI produced 0.6 degrees per year (i.e., half the degrees to African Americans at PWIs were awarded in departments that produced 0.6 or fewer degrees per year), while the median HBCU or PBI produced 3 degrees per year. Most of the degrees come from PWIs where African American physics students have few, if any, peers of the same race and ethnicity.

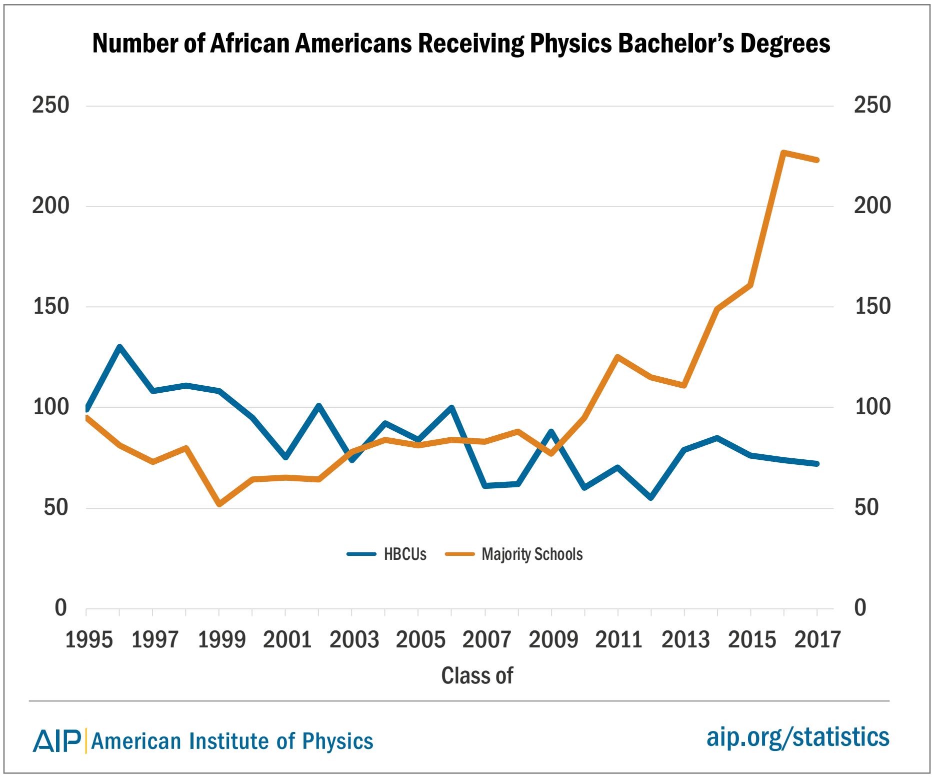


Figure 4: Change over time in the source of physics bachelor's degrees to African Americans.

In the past, HBCUs produced the majority of bachelor's degrees to African Americans in Physics. Figure 4 shows that the crossover happened around 2006. The percentage of degrees awarded to African Americans in physics increased after 2013 (Figure 1) because of gains made at PWIs.

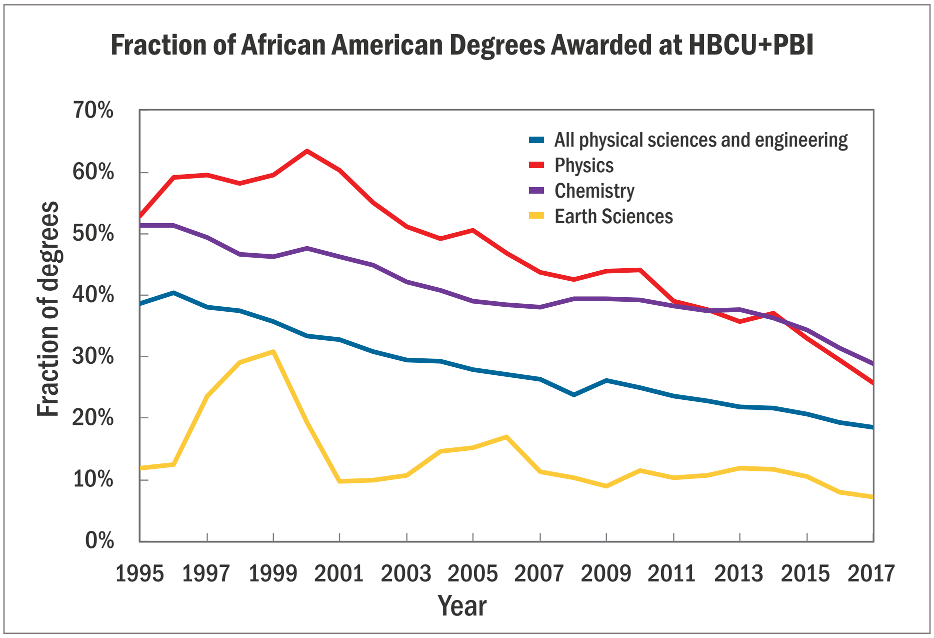


Figure 5: Fraction of bachelor's degrees to African Americans Awarded by HBCUs and PBIs, relative to all institutions. Physics shows greater losses than other, similar fields.

One of the reasons physics showed greater decreases than other fields in the physical sciences and engineering is because HBCUs showed greater percentage decreases in physics degrees than they did in other fields of science. Figure 5 shows the evidence.

The data shown above lead to three conclusions for African Americans in physics and astronomy:

1. African Americans obtain physics and astronomy degrees at significantly lower rates than other minorities and at lower rates than in the physical sciences and engineering overall.
2. The numbers have gotten steadily worse over the past 20 years, aside from a recent increase in African American degrees at PWIs.
3. HBCUs did not experience the growth in physics graduates occurring elsewhere following the SPIN-UP report. On the contrary, their programs declined.

Quantitative data alone cannot explain the causes underlying these conclusions. For that, qualitative research is necessary and provides the foundation for the rest of this report. Instead of focusing on the negatives, our approach is to identify factors that support student success, examining both PWIs and HBCUs. Although PBIs are few in number, they share some characteristics of HBCUs and provide a good comparison sample. Our site visits included all three types of institutions, as well as a mix of public and private schools and those whose highest degree is either bachelor's or doctorate (Appendix 5).

After undertaking these steps, individual researchers, department chairs and officers, and professional societies will be able to identify the next steps appropriate to their context from among the many other recommendations in the report.

APPENDIX 2: TEAM-UP SURVEY & NSBP INTERVIEWS

Overview

The student survey was designed to assess students' planned behaviors and intentions as well as their experiences in the major. The development of the survey was informed by the STEM Identity Model (Fries-Britt et al., a manuscript currently under review) to examine differences across ethnic groups as well as gender. The STEM identity model seeks to examine what drives and motivates underrepresented minority students in their pursuit of STEM degrees. The model considers the following key factors: 1) intentions to persist and to withdraw, 2) certainty of major, 3) financial concerns, 4) faculty interactions, 5) classroom self-efficacy, 6) self-efficacy as a physicist, 7) awareness of career opportunities, 8) learning strategies, 9) departmental belonging, 10) sense of community with peers of the same ethnic group, 11) importance of engaging in prosocial behaviors, 12) perceptions of prejudice, and 13) academic performance.

Our results should be considered at most an exploratory portrayal of differences among ethnic groups in the 13 factors under study. The statistical methods we use work best when the samples are balanced, a condition that is not met in our data because the samples of African American and White students are larger than the other two ethnic groups. Our sample may not be representative of the target population as well. Our efforts to increase the numbers of underrepresented minority students in physics by targeting conferences and professional organizations may have resulted in an unusual group of subjects with high levels of commitment to their major.

To augment survey data, interviews were conducted with 25 students. These interviews aligned with the central aim to examine faculty interactions, department climate, and the amplification of student voices and experiences. The interview protocol was informed by the findings of the survey to further explore student experiences in the major and department. Once interviews were transcribed and checked for accuracy, the research team coded the responses in teams of two. Using a constant comparative method, each transcript was reviewed to identify key themes and findings, and the full team made decisions about final data and categories.

Study Design and Methods, Conceptual Model and Findings

To understand the factors influencing Black students who are most at risk of not persisting in the major of physics or astronomy, or of stopping out of school, the TEAM-UP task force sought to identify potential leavers. Potential leavers were identified as those students who responded to question 9 on the survey in Appendix 3 with a high intention to leave based on a Likert scale score of 3 (agreeing) or 4 (strongly agreeing) across three categories (1) transfer to another university (2) stop out, and (3) change majors.

As noted above, the TEAM-UP student survey was designed to assess students' planned behaviors and intentions as well as their experiences in the major and was informed by the STEM Identity Model (Fries-Britt et. al., a manuscript currently under review).

To examine STEM identity, Fries-Britt et. al. constructed a conceptual model centered on three theoretical concepts: (1) a sense of belonging, (2) identity-based motivation theory, and (3) planned behavior theory. Planned behavior theory (Ajzen 1991) argues that *planned intentions* to engage in a particular behavior such as transferring from a college or dropping out of school are the best predictors of said behavior. Thus, when students talk about leaving the physics/astronomy major, they are more likely to follow through with these plans. Research on college persistence is consistent with the theory of planned behavior. Withdrawal decisions among college students have been found to be linked to their intentions to persist in college (e.g., Cabrera, Nora, and Castaneda 1992; Bean 1980; Bowman and Denson 2014; Haussman et al. 2007). Sense of belonging or social integration has been highlighted as a key factor in facilitating students' adjustment to and success in postsecondary education (Bollen and Hoyle 1990, Hurtado and Carter 1997, Cabrera et al. 1994, Spady 1971, Tinto 1987). To understand the importance of motivation, we focused on identity-based motivation theory (Drezner 2018, Leonardelli and Brewer 2001, Oyserman 2009, Tajfel and Turner 1979). Identity-Based Motivation theory (IBM) submits the proposition that individuals are driven to act in a manner that is congruent with their sense of belonging to a particular group, with whom they share values and behaviors.

Understanding Potential Leavers

Our analyses were based on undergraduate students pursuing physics/astronomy or double majors in physics. This subpopulation of 264 students represents 68% of the students who answered the TEAM-UP survey. The primary focus of TEAM-UP was to understand the experiences of the 101 students in this subpopulation who identified as Black and/or Black biracial. This group was evenly split between males and females. While we provide survey findings in this document on White, African American, Black biracial, and "Other" in the TEAM-UP report, we focus on the findings related to African American and Black biracial students.

Stopouts

A total of 79 students indicated high intentions of stopping out of college. Of these, nearly half identified as African American (30%) and/or Black biracial (17%). Of the 79 students, the overwhelming majority were physics majors (76%) and more than half were female (58%). African American students were slightly more prone to report high intentions to stop out compared with White students (31% versus 28%). Nearly all of the students (93%) who indicated that they might stop out attended Predominantly White Institutions (PWIs) with doctoral research universities representing 59% of these institutions.

Potential stopouts identified several barriers that shaped their experiences. One of the most frequent themes for Black students was finance. Many of these students described a lack of funding overall as well as the need to manage a demanding work schedule so that they could pay for college. Even those with family assistance noted that it was still a challenge. As one student observed,

> "Because of my scholarship, I don't have to work to pay for school. However, I do have to work to cover my personal expenses. I end up losing… time that I'd prefer to spend studying."

A second barrier that was noted often by Black students was concern for their academic capital and ability to do the work. Students had challenges understanding the materials and needed additional help to grasp concepts. Students who considered stopping out had limited exposure to physics prior to college or limited math skills, which made the work more challenging. Several students mentioned that they did not have college-educated parents who could help them with their academics. Additionally, potential stopouts noted that their own study habits needed to improve and that they did not feel comfortable reaching out for help. Finally, potential stopouts did not feel a strong sense of belonging, as there were few African Americans in their departments. This is represented by the comments of a student who noted,

> "Not seeing people like me in professor or even grad positions. Not really having a confidant within the department. Feeling incapable of doing the work and feeling less than."

Intent to change majors

A total of 58 students indicated high intentions to potentially change their major. Males and females were evenly split in this group. Of the 58, African American students made up the highest proportion to report high intentions to change majors (35%). The majority of students who were prone to change majors said they were pursuing a physics major (73%). Also, most of the students prone to change majors were attending Predominantly White Institutions (85%).

Students at risk of changing their major identified interactions with faculty and the department as two of the most important barriers. Students talked about the negative interactions they had had with faculty and feeling unsupported. Professors who were not passionate about what they taught, professors whose teaching style made things harder to understand, and encountering implicit bias in the classroom were factors that made it difficult for students to be in the classroom. Similar to potential stopouts, finances were also mentioned often by students' who were considering changing their major. These students noted very similar issues of affordability and having to work to earn money to pay for school. The need to work results in less time for students to study and keep up with the demands of a physics major. Students who work often have less time to be engaged in research and other important opportunities like attending conferences and studying with peers. Essentially students at risk of changing their major noted barriers related to managing the demands of work and other life commitments including academics.

Intent to transfer

A total of 64 students indicated high intentions to potentially transfer to another institution. Males and females were evenly split in this group, and Black and other underrepresented minorities represented 76% of this potential transfer category. The majority of the students (73%) were enrolled as physics majors, and the overwhelming majority were attending Predominantly White Institutions (85%), with doctoral research institutions representing 73%.

Students who expressed an interest in transferring mentioned many of the same issues as their peers who were considering stopping out or changing majors. They were concerned about paying for college and balancing the demands of work and school. They were also concerned about classroom practices and workload in the major and having support from faculty and the department to be successful in the major. An area that also emerged was mental health and the ability to remain positive and motivated to do their work. Students noted that the various stresses were having an impact on their motivation to succeed, deal with procrastination and handle their sense of impostor syndrome as they worked with faculty and peers.

Examining Ethnic Group Differences

The first research question guiding the analysis of ethnic difference was:

- Among undergraduate students pursuing physics majors (or majors with physics emphasis) at Predominantly White Institutions, what differences are there among ethnic groups in relation to key factors of their collegiate experience?

Our target sample consisted of 167 undergraduate physics students enrolled at Predominantly White Institutions (PWI). This sample accounts for almost 90% of all students pursuing physics majors or related ones, hereby referred to as PhM. As shown in Table 1, the overwhelming majority of PhM African Americans reported attending PWIs (78%). It is also important to note that the small number of PhM students enrolled at Minority-Serving Institutions (MSIs) renders statistical comparisons with PWIs unfeasible.

	Predominantly White Institution (PWI)		Minority-Serving Institution (MSI)		Total	
Ethnicity	N	%	N	%	N	%
White	53	96.4	2	3.6	55	29.4
African American	52	77.6	15	22.4	67	35.8
Black Biracial	32	94.1	2	5.9	34	18.2
Other	30	96.8	1	3.2	31	16.5
Total	167	89.3	20	10.7	187	100

Table 1. Distribution of undergraduate students pursuing physics (or physics-related fields) across type of institution

Analysis

We relied on ANOVA followed by Bonferroni tests among means to answer our research question. Among several methods to examine comparisons among means, the Bonferroni correction has the advantage of reducing the possibility of finding significant differences by chance, also known as type I error (Castañeda, Levin, and Dunham 1993).

Limitations

Our results should be considered at most an exploratory portrayal of differences among ethnic groups in the 13 factors under study. ANOVA and Bonferroni work best when the samples are balanced, a condition that is not met in our data. The samples of African American and White students are larger than those of the other two ethnic groups. Our sample may not be representative of the target population as well. Our efforts to increase the numbers of underrepresented minority students in physics by targeting conferences and professional organizations may have resulted in an unusual group of subjects with high levels of commitment to their major.

Findings by Ethnicity

Means, corresponding standard deviations, F-tests and their associated p-values, and Bonferroni tests of means are reported in Table 2 (page 32) across all 13 factors. It is important to note that the means reflect the Likert scale used in appraising the corresponding item, ordered by level of intensity. Accordingly, the higher the mean, the higher the level of agreement about the item. A summary of key findings is provided on page 33.

Factor/indicator	Overall N=167		African Am (AA) n= 52		Black-Biracial (BB) n = 32		White (W) n = 53		Other (O) n = 30		F-test	p-value	Significant Mean Comparisons (Bonferroni)
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.			
Intent to persist													
Completing major at institution	3.66	0.64	3.69	0.54	3.72	0.63	3.70	0.61	3.47	0.82	1.10	0.35	None
Intent to withdraw													
Transferring to another inst.	1.88	0.96	2.04	0.95	1.71	0.97	1.73	0.84	2.07	1.10	1.60	0.19	None
Changing majors	1.92	0.91	1.96	0.90	1.81	0.91	1.90	0.89	1.96	0.99	0.21	0.89	None
Leave field after degree	1.79	0.86	1.73	0.75	1.74	0.82	1,82	0.93	1.90	0.99	0.31	0.82	None
Certainty of Major													
Majoring in Physics right choice	3.30	0.78	3.24	0.79	3.09	0.94	3.40	0.71	3.45	0.68	1.12	0.34	None
Important to be a physicist	3.16	0.87	3.24	0.85	2.91	0.94	3.10	0.90	3.40	0.68	1.31	0.28	None
Financial concerns													
Paying for college	2.82	1.10	2.83	1.20	2.78	1.0	2.70	1.07	3.10	1.06	0.95	0.42	None
Working interf. studies	2.46	1.13	2.44	1.18	2.41	1.2	2.47	1.03	2.50	1.97	0.04	0.99	None
Paying college debt	2.60	1.21	2.79	1.18	2.56	1.2	2.64	1.18	2.90	1.24	2.46	0.06	None
Faculty interactions													
Phys fac encourage class part	4.07	1.13	4.08	1.20	4.25	0.84	3.63	1.40	3.63	1.40	2.07	0.11	None
Phys fac interested in my ideas	4.02	1.20	4.06	1.18	4.25	0.98	4.09	1.15	3.59	1.48	1.76	0.16	None
Comfortable approaching fac	4.16	1.09	3.94	1.19	4.35	0.84	4.36	0.90	3.97	1.38	1.94	0.13	None
Fac affirm ability to do physics	3.10	0.90	3.08	0.86	3.22	0.79	3.13	0.94	2.93	0.99	0.56	0.64	None
Classroom Self-Efficacy													
Confident on physics assignments	4.06	0.98	3.90	1.14	4.03	0.78	4.28	0.89	3.97	0.99	1.47	0.23	None
Doing excel job physic exams	3.66	1.14	3.42	1.25	3.69	0.93	3.94	1.05	3.57	1.25	1.93	0.21	None
Confident handling lab equip	4.05	1.10	4.08	1.10	4.06	1.17	4.00	1.36	4.07	1.01	0.03	0.99	None
Self-efficacy as a physicist													
See oneself as physicist	3.36	0.74	3.37	0.71	3.22	0.71	3.43	0.82	3.37	0.67	0.57	0.64	None
Others regard one as physicist	2.96	0.90	3.00	0.95	2.97	0.82	3.02	0.91	2.80	0.92	0.42	0.74	None
Awareness of career opport.	2.83	0.88	2.98	0.89	2.72	0.89	2.85	0.91	2.63	0.76	1.20	0.31	None
Learning strategies													
Seek help from peers	3.26	0.87	3.15	0.94	3.41	0.61	3.28	0.86	3.27	1.01	0.56	0.64	None
Seek help from professor	3.04	0.87	3.10	0.87	3.00	0.92	3.08	0.85	2.90	0.88	0.38	0.77	None
Seek help from online resources	3.50	0.70	3.59	0.69	3.50	0.57	3.43	0.74	3.47	0.78	0.50	0.68	None
Departmental belonging													
Belonging academic dept comm	3.97	1.22	3.96	1.10	3.90	1.28	4.13	1.24	3.76	1.35	0.61	0.61	None
Community with peers in major	3.86	1.26	3.69	1.24	3.69	1.25	4.15	1.12	3.67	1.47	1.51	0.21	None
Departmental supportive env.	4.15	1.03	4.12	1.09	4.38	0.87	4.30	0.85	3.73	1.28	2.59	0.05	0 < W**; 0 < BB**
Sense of community with peers of same ethnic group	3.53	1.31	4.04	1.07	3.21	1.21	3.66	1.33	2.77	1.33	7.63	0.01	BB< AA**; 0< W**; 0<AA**
Pro-social behaviors													
Organizations that improve soc	3.39	0.67	3.50	0.70	3.09	0.77	3.42	0.57	3.50	0.57	2.97	0.03	BB < AA**; BB < 0*
Making the world a better place	3.49	0.68	3.58	0.64	3.22	0.87	3.62	0.56	3.40	0.62	2.97	0.03	BB < W**; BB<AA*
Benefit own community	3.29	0.88	3.65	0.59	3.16	0.92	3.21	0.95	3.00	0.98	4.73	0.03	W<AA**; BB<AA*;0<AA***
Mentor others in the major	3.51	0.79	3.62	0.69	3.28	0.81	3.55	0.64	3.50	0.68	1.59	0.19	None
Perceptions of prejudice													
Treated negative in class & labs	1.55	1.09	1.92	1.33	1.21	0.49	1.33	0.97	1.57	1.07	3.79	0.01	W<AA**; BB<AA**
Seen other treated negatively	1.57	1.03	1.78	1.30	1.23	0.50	1.52	0.84	1.23	0.50	1.88	0.13	None
Academic Performance													
Overall	3.50	0.74	3.31	0.73	3.32	0.65	3.81	0.74	3.47	0.68	5.35	0.01	AA<W**; BB<W**
In the major	3.51	0.82	3.30	0.81	3.26	0.86	3.85	0.75	3.57	0.73	5.45	0.01	AA<W**; BB<W**
Notes: * p < .10; ** p < .05; *** p < .01													

References: Castaneda, M. B., Levin, J. R. & Dunham, R. (1993). Using planned comparisons in management research: A case for the Bonferroni procedure. Journal of Management, 19(3), 707-724.

Table 2 references differences in adjustment to college and planned behaviors within Predominantly White Institutions.

1. *Intent to persist.* There is no significant association between intent to persist and the ethnic group the student belongs to. On a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree), all ethnic groups displayed a strong commitment to completing the major at the institution where they are currently enrolled (q9).

2. *Intent to withdraw.* We found no significant association between ethnicity and intent to withdraw. On a 4-point Likert scale, all students, irrespective of their ethnic affiliation, reported low intention to transfer to another institution (q9a), change majors (q9d), or leave the field after completion of the degree.

3. *Financial concerns.* On a 4-point Likert scale, all students reported moderate levels of concern about paying for college (q24a) and the extent to which work interferes with studies (q24b). The association between ethnicity and these two sorts of financial concerns was not significant. However, concerns about paying back student debt (q24c) displayed a significant association with ethnicity. While the Bonferroni test could not single out a particular ethnic group responsible for this association, African Americans did display the highest average for this sort of financial concern (2.79 on a 4-point scale).

4. *Faculty interactions.* We found no significant association between ethnicity and our four indicators of faculty interactions. On a 5-point Likert scale, all students reported high levels of agreement in characterizing faculty as encouraging class participation (q13a) and being genuinely interested in their ideas and opinions (q13b). All ethnic groups showed high levels of agreement that faculty are approachable for help in understanding concepts discussed in class (q13c). Notably, PhM students, irrespective of ethnicity, agreed that faculty affirm their ability to do physics (q15c).

5. *Classroom self-efficacy.* All ethnic groups displayed similar means in their confidence of doing an excellent job on physics assignments (q12a) and physics exams (q12b), and in their confidence operating lab materials and equipment (q12c). On a Likert scale ranging from 1 (never) to 5 (most times), their means are around 4 (sometimes).

6. *Self-efficacy as a physicist.* There are no mean differences in PhM students' perceptions of themselves as a physicist (q17a), or their belief that others regard them as one (q17b). However, it is important to note that students' self-perception as a physicist displayed higher means across all ethnic groups compared with the same ethnic groups' beliefs that others perceive them as a physicist.

7. *Awareness of career opportunities.* We found no significant association between ethnicity and awareness of career opportunities (q20). All ethnic groups displayed high levels of awareness of jobs and career opportunities open to physics majors.

8. *Learning strategies.* PhM students, irrespective of their ethnic group, displayed high levels of engagement in a variety of learning strategies. These include seeking help from peers (q15a), from the professor (q15b), and from online resources (q15e). The only notable difference is one displayed by students with a variety ethnic background ("Other" ethnic category). This ethnic group has the lowest mean in seeking help from the professor although not statistically different.

9. *Departmental belonging.* All ethnic groups displayed high levels of sense of belonging with the departmental community (q11a) and with peers in the major (q11b). On a 1-5 point Likert scale, the means are close to 4. However, PhM students' perceptions of the extent to which the department creates a supportive environment (q11d) do differ by ethnic group. Students with a diversity of ethnic backgrounds (Other) do display lower levels of perception of a supportive departmental environment compared with White and Black biracial students.

10. *Sense of community with peers of the same ethnic group.* We found significant ethnic differences in the extent to which PhM students perceive a sense of community with peers of the same ethnic identity (q11c). African American students reported high levels of a sense of community with members of their own ethnic group compared with Black biracial students, and those in the "Other" ethnic category. Whites also displayed higher levels of cohesion compared with students with a diverse ethnic background ("Other").

11. *Prosocial behaviors.* This dimension consists of plans and commitments the PhM student has toward four prosocial behaviors. These are: being involved in organizations that promote the use of physics to improve society (q21b), having a career that makes the world a better place (q21c), being committed to the benefit of the ethnic or religious community the student belongs to (q21d), and commitment to mentor others interested in their major (q21e). With the sole exception of mentor commitments, prosocial behaviors do vary across ethnic groups. Compared with White and "Other" multiracial students, African Americans are more committed to being involved in organizations that improve society. Likewise, African American students are more interested in making the world a better place than are Black biracial students. Moreover, African Americans displayed higher levels of commitment to benefit their own ethnic and religious communities than did Whites, Black biracial students, and "Other" multiracial students. All ethnic groups displayed similarly high levels of interest in mentoring others in their major.

12. *Perceptions of prejudice.* This factor captures exposure to prejudice and discrimination in physics classes or labs. These experiences include being personally treated negatively because of race or ethnicity (q13d) and witnessing others being treated negatively because of race or ethnicity (q13e). All students, irrespective of their ethnic affiliation, reported low levels of witnessing prejudice aimed at underrepresented minority (URM) students. However, exposure to a negative classroom climate does vary by ethnic group. African Americans reported higher levels of exposure to classroom-based prejudice compared with White and Black biracial students.

13. *Academic performance.* Overall cumulative GPA and cumulative GPA in the major do vary across ethnic groups. On average, African Americans reported lower overall GPA and cumulative GPA in the major compared with Whites. The same observation holds for Black biracial students.

Examining Gender Differences

The second research question guiding our gender analysis, was:

- Among undergraduate students pursuing majors in physics (or majors with physics emphasis), what differences exist between men and women in relation to key factors of their collegiate experience?

Target sample

Our target sample consisted of 198 undergraduate male and female students pursuing physics (or physics-related) majors. Slightly over half (53.5%) of the sample was composed of females. Males accounted for 46.5% of the sample.

Choice of major

Students' major and gender are significantly associated ($X^2 = 7.33$, $p < .05$). As shown in Table 3, the majority of women reported pursuing physics majors (65%). Astronomy/astrophysics constituted the second-most-popular major (23%), and 12% of women pursued double majors. The majority of men, in contrast to women, reported pursuing physics majors only (82%). Astronomy/astrophysics constituted a distant second choice of majors (14%) for this group. Men were less likely to report pursuing double majors than were women (4.4% versus 12.3%).

Major	Male		Female		Total	
	N	%	N	%	N	%
Astronomy/Astrophysics	13	14.13	24	22.64	37	18.69
Physics	75	81.52	69	65.09	144	72.73
Double Major	4	4.35	13	12.26	17	8.59
Total	*92*	*100*	*106*	*100*	*198*	*100*
$X^2 = 7.33$, $p < .05$; Cramer's V = 0.19						

Table 3. Distribution of undergraduate students pursuing physics (or physics related fields) by gender

Ethnicity characteristics

There are no discernible ethnicity-based patterns identified in our sample. The association between ethnicity and gender is nonsignificant ($X^2 = 0.853$, $p > .05$). As shown in Table 4, nearly 38% of the male sample is African American. Just over a quarter of the male sample is composed of Whites. Among female students, African Americans represent 34% of the sample. White females account for just under one-third of the sample.

Ethnicity	Male		Female		Total	
	N	%	N	%	N	%
White	24	26.67	33	31.13	57	29.08
African American	34	37.78	36	33.96	70	35.71
Black biracial	16	17.78	16	15.09	32	16.33
Other	16	17.78	21	19.81	37	18.88
Total	*90*	*100*	*106*	*100*	*196*	*100*
$X^2 = 0.853$ $p > .05$; Cramer's V = 0.06						

Table 4. Distribution of undergraduate students pursuing physics, or physics related fields by ethnicity and gender

Institutional attendance patterns

We also examined attendance patterns by Title IV and Carnegie institutional classifications. There is no significant association between a student's gender and attendance at either a Title IV ($X^2 = 0.55$, $p > .05$) or a Carnegie institutional classification ($X^2 = 6.47$, $p > .05$). The majority of men and women attended Predominantly White Institutions (PWIs). Men and women attended doctoral institutions at comparable rates (56.3% among men and 57.6% among women) (see Figure 1).

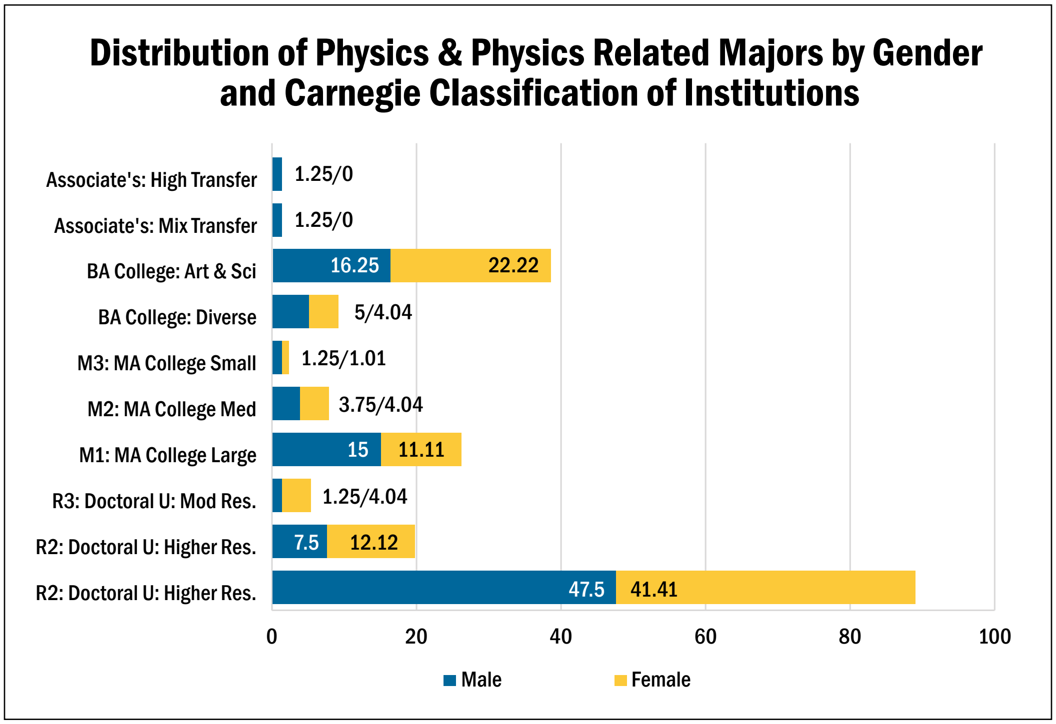


Figure 1: Percentage of undergraduate students pursuing physics and physics related majors by gender and Carnegie Classification of Institutions.
Source: TEAM UP Student Survey

Analysis

We used *t*-tests among *means* to answer our research question.

Limitations

Our results should be considered, at most, an exploration of gender differences across the 14 factors under consideration below. Our sample may not be representative of women pursuing physics majors. Our efforts to increase the numbers of underrepresented minority students in physics by targeting conferences and professional organizations may have resulted in an uncharacteristic group of underrepresented students with higher levels of commitment to their major.

Findings by Gender

Means, corresponding standard deviations, *t*-tests, and their associated p-values are reported in Table 4 across all 14 factors. It is important to note that the means reflect the particular Likert scale used in appraising the corresponding item. Some items asked for frequencies (e.g., q11), while others called for level of agreement (e.g., q17). However, all Likert scales are ordered by level of intensity. Accordingly, the higher the mean, the higher the level of agreement/frequency with the item. A summary of key findings is provided below.

1. *Intent to persist.* There is no significant association between intent to persist and gender. On a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree), women are as strongly committed to completing their major as men (q9).

2. *Intent to withdraw.* We found no significant association between gender and intent to withdraw. On a 4-point Likert scale, all students, irrespective of their gender, reported low intentions of transferring to another institution (q9a), changing majors (q9d), or leaving the field after completion of the degree (q9c).

3. *Certainty of major.* We found a significant association between gender and certainty of major. To a statistically significant degree, women gave less importance to becoming a physicist (q22b) and reported less certainty about majoring in physics (q22a) than men did.

4. *Financial concerns.* Men and women displayed similarly moderate levels of concern about paying for college (q24a) and about the extent to which work interferes with their studies (q24b). The association between gender and these two sorts of financial concern is not significant. However, concerns about paying for college debt (q24c) displayed a significant association with gender. On average, women are more concerned about paying for college debt than are males (2.76 versus 2.4 on a 4-point scale).

5. *Faculty interactions.* We found a significant association between gender and three of our four indicators of frequency of faculty interactions. Women reported lower levels in the frequency with which physics faculty affirm their ability to do physics (q15c) and encourage their class participation (q13a). Women also report less frequency in approaching physics faculty to discuss topics covered in class (q13c). On the other hand, men and women report similar levels in the frequency with which physics faculty express interest in their ideas (q13b)—4.18 versus 3.92 on a 5-point scale.

6. *Classroom self-efficacy.* As a whole, women displayed lower levels of classroom self-efficacy in comparison with men. With the exception of their confidence in handling lab material and equipment (q12c), women are less confident in doing a good job on physics exams (q12b) and on physics assignments (q12a).

7. *Self-efficacy as a physicist.* Women are less self-efficacious as a physicist than are men. They are slightly less likely to perceive themselves as physicists (q17a) and slightly less likely to believe that others regard them as one (q17b).

8. *Awareness of career opportunities.* We found no significant association between gender and awareness of career opportunities (q20). On a 4-point Likert scale, men and women reported high levels of awareness of jobs and career opportunities open to physics majors (2.99 versus 2.79).

9. *Learning strategies.* Both men and women displayed similar means in reporting seeking help from peers (q15a) and from online resources (q15c). However, women reported less frequency in seeking help from their professor than did men (q15b).

10. *Departmental belonging.* Men and women displayed high levels of a sense of belonging with the departmental community (q11a) and with peers in their major (q11b). On a 5-point Likert scale, their means are close to 4. However, women reported lower levels of a supportive departmental environment (q11d) in comparison with that reported by men.

11. *Sense of community with peers of the same ethnic group.* We found no significant gender differences in the extent to which students perceive a sense of community with peers of the same ethnic identity (q11c).

12. *Prosocial behaviors.* This dimension consists of plans and commitments the student has toward four prosocial behaviors. These are: being involved in organizations that promote the use of physics to improve society (q21b), having a career that makes the world a better place (q21c), being committed to the benefit of the ethnic or religious community the student belongs to (q21d), and commitment to mentor others interested in their major (q21e). We found no gender differences. Men and women displayed similarly high levels of commitment to engage in these four prosocial behaviors. On a 4-point Likert scale, the means are above 3 (agree).

13. *Perceptions of prejudice.* This factor captures exposure to prejudice and discrimination in physics classes or labs. Those experiences include being personally treated negatively because of race or ethnicity (q13d) and witnessing others being treated negatively because of their race or ethnicity (q13e). All students, irrespective of their gender, reported low levels of witnessing prejudice aimed at other URM students or receiving such prejudiced treatment themselves.

14. *Academic performance.* On average, women reported lower overall GPA than men reported. However, their academic performance in the major is similar to that of men.

Survey Open-Ended Questions

The survey included four open-ended questions. Through inductive coding processes the team examined responses to each question. Once responses for each open-ended question were coded, the committee reviewed all coding decisions and agreed on the final themes that emerged from the data. What follows is a brief overview of each question and related demographics. We used students' responses to q33 (*What has been a barrier to success in your undergraduate career?*) to provide insights into why they may have considered potentially leaving. We provide racial demographics for student responses to q33 as this question informed the survey findings.

While not all students who intended to transfer, stop out, or change majors identified barriers, the responses to q33 provide important insights from potential leavers about their experiences. Student responses to q33 cannot be directly correlated as reasons for students' intentions to transfer, stop out or change majors. Rather, these data provide additional context and important insights into the types of experiences that students have navigated as physics and astronomy majors and in their academic career in general.

Q-31—How did you decide upon your current major? If you are undecided, what do you think will help you decide?

- A total of 210 participants provided responses to this question, and of this group 108 were females and 94 were males. There were also 6 gender nonconforming, 1 participant who selected "Other," and 1 who preferred not to answer. In terms of class standing, there were 15 freshmen, 46 sophomores, 59 juniors, and 90 seniors.

- In order of prevalence of topics with 10 or more responses, the following eight items were cited most often as being most influential in decisions to pursue physics: curiosity about/interest in physics (110 responses), early interest in physics (31), close alignment of physics to engineering (27), precollege preparation (24), postgraduate plans (22), aptitude for physics (16), K–12 physics teacher influence/encouragement (11), and extracurricular activities (10).

Q-32—What has helped you to succeed in your undergraduate career?

- A total of 203 participants responded to this question. Five students reported that there were no clear supports that aided in their success, with responses including "Nothing" and "I wish I knew". Eliminating these 5 respondents, a total of 198 individuals were included in the final analysis. Of the 198 respondents, 14 identified as freshmen, 40 identified as sophomores, 55 identified as juniors, and 89 identified as seniors. In terms of gender 102 were female, 88 were male, 6 were gender-nonconforming, 1 selected "Other," and 1 preferred not to respond. In terms of racial classification 72 identified as Black, 52 identified as White, 35 identified as Black-multiracial and 39 selected "Other."

- Ten major themes were salient, as follows (in order of frequency): peers (80), positive faculty/adviser/departmental interactions (79), academic capital (46), family (37), self-efficacy and goal orientation (35), encouragement from mentors and others in and outside STEM fields (27), mental health/self-care strategies (16), technology (12), time management/self-discipline (10), and research teams/internships (10). All other response themes had frequencies of less than 10 and were categorized as miscellaneous.

Q-33—What has been a barrier to success in your undergraduate career?

- A total of 203 participants responded to Q-33. Seven students reported not experiencing any barriers (with responses such as "N/A" and "I can't think of anything"), resulting in 196 participants reporting barriers to their undergraduate success. Of these, 105 identified as female, 83 identified as male, 7 identified as gender-nonconforming, and 1 participant selected "Prefer not to answer." Thirteen identified as freshmen, 39 identified as sophomores, 59 identified as juniors, and 85 identified as seniors. Finally, of the 196 participants who reported experiencing barriers, 75 identified as Black, 48 identified as White, 31 identified as multiracial with Black being one of their racial identities, 41 identified as "Other," and 1 participant preferred not to respond.

- Ten major themes were salient, as follows (in order of frequency): finances (41), mental health/motivation (32), curriculum (29), imposter syndrome (26), academic capital (25), faculty interactions (25), sense of belonging (20), department/college culture (16), lack of resources (11), and other commitments (11). All other response themes had frequencies of less than 10 and were categorized as miscellaneous.

- The most frequent theme for Black students was finances (15), followed closely by academic capital (13) and sense of belonging (12). The most frequent themes for White students were finances (12) and mental health/motivation (also 12). Finances (6) and imposter syndrome (6) were the most frequent themes for Black-multiracial students. The most frequent theme for female participants was finances (20), followed very closely by imposter syndrome (19). The most frequent theme for male participants was finances (19) followed by curriculum (17).

Q-36—Is there anything that you would like to tell us about your undergraduate experience?

- A total of 111 people responded to this question. Of these, 17 individuals wrote "NA" or a similar response. These individuals were eliminated, resulting in 94 individuals included in the data. Of the 94 participants, 45 were female, 46 were male, 2 were nonconforming, and 1 preferred not to say. In terms of class standing, there were 44 seniors, 25 juniors, 19 sophomores, and 6 freshmen.

- Analysis of the responses revealed three key themes: direct observations about physics/STEM field (32), academic/social experiences (32), and overall climate and issues of discrimination (9)

Focus Group Data

Interviews were conducted with 25 students at the 2018 National Society of Black Physicists (NSBP) conference in Columbus, Ohio. In attending a physics conference, interviewees were showing a commitment to physics that might be greater than that of the average survey respondent. These interviews aligned with the central aim to examine faculty interactions, department climate, and the amplification of student voices and experiences. We conducted six focus groups involving a total of 11 males and 14 females. There were 1 freshman, 4 sophomores, 10 juniors, 9 seniors, and 1 student whose class standing was not reported in the focus group or the on-line demographic survey. Based on a few comments that the student offered we note that she was likely a sophomore or junior.

Method and analysis

The interview protocol was informed by the findings of the survey to further explore student experiences in the major and department. Once interviews were transcribed and checked for accuracy, the research team coded the responses in teams of two. Using a constant comparative method, each transcript was reviewed to identify key themes and findings, and the full team made decisions about final data and categories.

Major Themes and Findings

Interactions and experiences with professors

As might be expected, students reported a wide range of experiences and interactions with professors, including extremely positive and negative experiences. However, across all groups, students had positive things to say about faculty in general and saw them as generally good and supportive.

When students talked about professors who were very effective, they gave examples of their effective classroom practices—how they affirmed students' academic abilities, encouraged their success, helped them network and find resources, and demonstrated a high level of commitment to students. These professors were seen as game changers and operated with a high degree of care and interest in students and their teaching. They tended to have very strong reputations in the department and were well known among students.

Students who discussed having negative experiences with faculty often had encounters with faculty who questioned their academic work and potential. They encountered faculty who asked why they were majoring in physics or suggested that they change majors or drop out of college entirely. These professors were perceived as insensitive, generally unsupportive, and not interested in helping students learn the material. In a few examples, students wondered if faculty were racist or sexist.

Positive examples

"I had to take a break from doing research for a while with the professor that I had been doing research with just because I was like, 'I want to be able to put my full effort, but I don't know if I can at the moment.' Then he was still inviting me to conferences, inviting me to telecons and that kind of thing. He was still trying to keep me included and asking how everything was going and if I needed anything. I just appreciated that ongoing support even though I couldn't be there the full amount of time."

"I think that I encountered my best instructors when I took quantum, and those were two of the hardest semesters ever, but they both had open doors at the time and were really open to you just—most professors are, and they're very confused why people don't come and ask them questions, but I don't know, they're both just really easy to talk to, very clear in class, really, really explained everything, accepted all questions inside and outside of the classroom, and I didn't feel they expected less of me or didn't feel I belonged in the class because I was the only black woman, black person, in the classroom."

Negative examples

> "I actually had pretty terrible professors who didn't care, didn't encourage. My academic adviser would make me cry, and my faculty adviser hinted at me dropping out of college and just learning how to code on my own because my midterm grades weren't what she expected them to be. And until this semester I've just been like, 'This is not what I thought college was supposed to be.' It was just completely discouraging, and I was like, 'What's actually happening here? I hate this.' "

> "He was like, 'Well, obviously you weren't trying hard enough. If you want the grades, you need to work for the grade.' I was asking if there's any help or extra credit because not everybody learns the same way. When it comes to teachers like that, it makes you want to give up and it demeans you. [Laughs.] It wasn't even just me. My school is an HBCU, so there's a lot, but he had favorites. Most of his favorites were not of the HBCU variety. [Laughs.] He treated us like we were second-class citizens… No one's a second-class person."

> "He constantly refers to everybody as 'gentlemen.' He never says, 'ladies and gentlemen.' He says things like 'You gentleman can do this.' I don't think he really recognizes me."

Department Culture and Student Experiences

Across all groups, the majority of students expressed a positive departmental culture. They described the culture as welcoming, and they felt that their peers, staff, and faculty were supportive. While the comments were generally positive, there were occasions when students were not clear what we meant by *department*. A few students also made distinctions between staff and faculty, noting in a few cases that the staff were particularly helpful and made the department more welcoming. There were students who felt they could go see any professor in their department to ask a question and were confident that they would be received positively and get help and support.

A number of students were in small departments, and this was key in shaping the overall climate "because everyone knows everyone, so it was important to interact and get to know folks". Students appreciated the support they received from the department for resources, for connections to important research experiences and opportunities in the field.

Department examples

> "I haven't had a black STEM professor yet. That's one thing that I envy, people that go to HBCUs, that they have that type of connection. Yesterday I was looking at the faculty and staff of my physics department and I didn't see any black faculty on it. It's not necessarily discouraging, but it's like, 'Okay, I guess.' You got to push through; but coming here to this conference, it honestly makes me happy to see this many black people in physics and black people in astronomy."

> "I wouldn't say people don't care. It's just that you could tell that people at PWIs are a lot more oriented on their own task. I don't say it's selfish, but they're a little more selfish toward their own goals."

Counterspaces

Students talked quite a bit about the importance of different communities like peers, family, and other role models whom they turned to for help and to support them in their academic work. There were examples of meeting with other students of color for mutual support. Many students were involved in minority-oriented programs, and attending NSBP was a huge highlight and eye-opener for those who had never been before. One quote stood out from a student who was talking about where they go for help when they have no support in their department. This student had transferred from a community college and talked about going back to the community college for help.

> "At community college, our curriculum is just to set us to go straight to [name of four-year college]...You complete this session at [name of community college] and they just throw us in a pool at [the four-year] college. No representation. No study groups, nothing. Just there by yourself. A lot of my friends that graduated ahead of me said they're either struggling or they're trying to survive; they have to come back to [name of community college] to seek help rather than seeking help at the senior college."

NSBP examples

> "I really enjoy that there are so many people here that look like me and that have the same interests as me. Last night there was the [special event] that I went to, and we started off and we were talking about different things about my field and of the sort. After we got our food, we went just straight into a nerd—we were talking about so many different nerdy things. It's not even just me; we're talking about, like, the PhD students next to us, some of the professors and things like that. That was really heartwarming. A lot of the research things for me—a lot of the stuff does go over my head because I'm just not at that level yet, but I'm still just sitting there, I'm clapping out and I was like, 'Yes, you go man. [Laughs.] I don't understand what you just said, but it looked real cool.' "

> "I'm like, 'Whoa, there are actually other women physicists and, you know, like, more men who are black and physicists.' I just felt a lot more confident just seeing all these different opportunities, too, and people who are trying to actively include you in them. It was really awesome."

Salient Cross-Cutting Themes for African American Students

(Based on survey findings, open-ended questions, and focus group data)

Financial concerns

Finances were one of the barriers most cited by all students, and African American students referenced this concern more than any other. Students stressed how financial concerns impacted their ability to focus on their work. This is captured in the comment of a student who shared,

> "The biggest barrier for me was finance. It was really hard to succeed and make the most of my undergraduate experience when I was constantly worrying about feeding myself and paying for rent."

Similarly, another student noted how a lack of finances was impacting their well-being:

> "I am paying the cost of college on my own, so that is continuous financial stress. Working 20-plus hours a week, including overnights. Continuous and worsening mental health issues. Personal tragedies. Living at home in a nonideal situation. Lack of support from the college/department. Administrative issues with the college."

Work schedules made it difficult for students to meet with faculty, especially for students who worked off campus. The continual stress of worrying about money to pay for school and mounting debt cut across a number of comments and impacted all aspects of their lives, including dealing regularly with a lack of sleep. Many students were working not only to support themselves but also to support parents; some had small children and households to support. While not representative of all students, one student's circumstances illustrate the challenges and unique circumstances that some students can face while in college:

> "Having to work many hours to support my family. Both of my parents had [life-threatening illnesses] around the same time. Then [one parent] passed away… [the other parent] survived… and the government mistakenly [mislabeled my status]. My mental health was at stake because I couldn't remember any physics or math to do [my] research."

Departmental belonging

While the students who participated in the focus groups and those who commented on the survey described positive experiences in their departments, the students in the focus groups were much more positive. Focus group participants described the culture as welcoming and felt that their peers, staff, and faculty were supportive. Even those students who had negative experiences with the faculty still perceived a positive department culture. They described feeling well supported by the department economically, academically, and socially. Only a few individuals indicated that the department culture was really bad; one said it "sucked." Students did express a desire to see more faculty of color in the department, as well as students of color and female students.

Unlike the focus groups, several observations made in the open-ended questions on the survey suggested that the department culture could be discouraging, unwelcoming, and at times toxic. Some students said professors can be discouraging and lack effective teaching skills, the department climate discourages students from asking for help or asking questions, and the competitive nature of the field impacts the overall climate. Students also shared in response to the open-ended questions that they experience self-doubt when they see a lack of women and URMs. One reported,

> "a constant feeling that I am a representative, therefore I must be flawless";

another described

> "not seeing people like me in professor or even grad positions, not really having a confidant within the department… feeling incapable of doing the work and feeling less than."

Sense of community with peers of the same ethnic group

The qualitative data illustrate how important building a sense of community among peers in the same ethnic group is to African American students. Having peers also majoring in physics seemed to make a significant difference, as these individuals helped them navigate the major while supporting them in their studies. Students noted the importance of learning from upperclassmen and their journey in physics. They wanted a strong support network of peers and advisers who looked like them and would advocate on their behalf. Students also intentionally sought out peers outside of the physics major. Essentially, building a community of peers within the same ethnic group was important to overall success. One student reported the following as a barrier to success:

> "Feeling isolated in my department and my field and knowing that as I got further in my education, less and less people of color would be there."

Faculty interactions

Professors who were perceived as effective had classroom practices that helped students with their learning process. These professors affirmed students' academic abilities, encouraged their success, and helped them network to find resources. They also demonstrated a high level of commitment to students and were invested in their learning the materials. One praised,

> "office hours! And lots of time dedicated to truly understanding the concepts on the basis of learning rather than for exams."

These professors were seen as "game changers" as reflected in the comments of a student who noted,

> "There was one teacher that really, honestly, I was going to give up on physics and she changed everything. I mean, she was so passionate about teaching, she knew a lot about physics education and research… She just kept checking in on me, and she would make comments on my test like 'This is not so good. Come see me.' Then she would email me like, 'Did you see my comment? Come see me.' "

Effective professors operated with a high degree of care and interest in students and their teaching. They tended to have very strong reputations in the department and were well known among students. These professors showed significant support and encouragement, helping students make important connections for research and access to opportunities in the field.

Faculty who were perceived as less effective did not display good classroom practices, seemed less interested in helping students learn the subject matter, and, in the way in which they interacted with students and behaved in the classroom, tended to make the subject matter more difficult. Talking about these issues, a student noted,

> "The classes are disorganized yet extremely accelerated, graded harshly, and are often taught by professors who are not passionate… or well taught themselves in teaching. This makes it hard to get help with difficult subjects, since they either don't care to give good help or aren't good at giving help."

Similarly, another student commented,

> "Poor instruction was the biggest barrier. Teachers did not know the fundamentals of pedagogy and simply presented material and assigned work in ways that were detrimental to learning. Success in classes was determined by who could best teach themselves, and many students who had the ability to learn were abandoned because they needed a good teacher and none was provided."

Students also perceived that some faculty seemed to be less interested in working with URM students and helping them succeed. One said,

> "The physics teachers lacked any real motivation and help for underprivileged students to succeed. The climate of the physics department is very non-inclusive of people of color… They would say… like, you should change your major."

Hearing suggestions that they change their major seemed to be a common experience. Essentially these professors were perceived as insensitive, generally unsupportive, and not interested in helping students learn the material. In some instances students wondered if faculty were racist and/or sexist. As noted earlier in a longer quote under department culture, a student commented that her professor:

"constantly refers to everybody as 'gentlemen.' He never says, 'ladies and gentlemen.' He says things like 'You gentleman can do this.' I don't think he really recognizes me. He doesn't respond to my emails, ever."

Self-efficacy

Students noted that some of their classroom experiences had an impact on their self-efficacy. Several students perceived that their classmates thought that they were not as smart, and this impacted their access to study groups or assignment groups in the classroom. Participants also expressed feelings of imposter syndrome, self-doubt, and other examples of lower self-efficacy. Participants often compared themselves to others and perceived that they were not performing as well as their peers on exams and assignments. One respondent described imposter syndrome as a barrier in their education, noting that

"I think that my only barriers are mental, and I get so inside of my head sometimes and think that I can't do things [that] I can."

Other participants noted similar sentiments. One noted,

"[T]here's certain times in class when the professor would pose a question and I would have the answer. Then another student in the class who was present and happened to be a White male would be like, 'No, that's not right.' So I didn't propose my answer to the classes. I was embarrassed because I was like, 'I'm just going to get it wrong,' but ended up being right. Just things like that where your colleagues or other students around you just make [you] feel more doubtful. I'm trying to work around that and still have confidence despite their opinions."

On approaching a professor who was not a member of a minoritized group for help, another said,

"I'm just, like, 'I don't know if I feel very comfortable with this. I already know it's already hard for me to talk to you about this' because of the whole imposter syndrome and that kind of thing, which is something on the back of my mind."

Overall, many students questioned their belonging in the field of physics and discussed how their self-doubt can pose a barrier in their educational pursuits:

"A barrier for me would be just really self-doubt. Sometimes you don't always do as well on a test or on an assignment as you think you should have. You have to fight back those feelings of 'Can I really make it in physics?'"

This self-doubt is often fueled by feelings of stereotype threat. Stereotype threat is the fear of being at risk of conforming to a negative stereotype (Steele and Aronson 1995). When one participant discussed her feelings of stereotype threat, she stated,

"Sometimes you feel like you can do it, and then it's like, what if you can't?… You go into a class and you're the only [Black] person there. There's already the pressure of 'I have to be top notch. I have to do what I got to do.' I feel like sometimes that can get in the way of personal success."

While a weakened sense of belonging for some students was rooted in self-doubt, for others it was brought about by professors:

> "I've had two professors ask me why I'm in physics. They see how much I'm struggling. Like, 'Why are you still a physics major? Why do you want to do this?' Multiple times. It's like, 'Well, I'm here because this is what I want to do.' They're like, 'You're making your life difficult doing all this.' It's very discouraging when you hear [this]."

Despite feelings of imposter syndrome, self-doubt, and stereotype threat, many participants emphasized an internal desire to persist through challenges and difficult tasks. Participants expressed their ability to work hard, remain diligent, and persevere in order to achieve their goal of graduating with a degree in physics. To describe their internal motivation, participants used words and phrases such as *ambition, persistence, just keep pushing, putting in the hard work,* and *the grit*.

Giving back matters

African American students are very interested in giving back to their community and making the world a better place. They display higher levels of commitment to benefit their own ethnic and religious communities. Surveys and interviews affirmed that African American students have a strong commitment to helping those who are coming after them. This strong commitment to prosocial behavior is reflected in African American students' desire to be involved in organizations that improve society. Like their non–African American peers, they also express an interest in mentoring others in the major.

References for Appendix 2

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, 50(2), 179–211.

Bean, J. P. (1980). Dropouts and turnover: The synthesis and test of a causal model of student attrition. *Research in Higher Education*, 12(2) 155–187.

Bollen, K. A., & Hoyle, R. H (1990). Perceived Cohesion: A Conceptual and Empirical Examination. *Social Forces*, 69, 479–504.

Bowman, N. A., & Denson, N. (2014). A missing piece of the departure puzzle: Student- institution fit and intent to persist. *Research in Higher Education*, 55, 123–142.

Cabrera, A. F., Castañeda, M. B., Nora, A., & Hengstler, D. (1992). The convergence between two theories of college persistence. *Journal of Higher Education*, 63(2), 143–164.

Cabrera, A. F., & Nora, A. (1994). College students' perceptions of prejudice and discrimination and their feelings of alienation: A construct validation approach. *Review of Education/Pedagogy/Cultural Studies*, 16(3-4), 387–409.

Castañeda, M. B., Levin, J. R., & Dunham, R. B. (1993). Using planned comparisons in management research: A case for the Bonferroni procedure. *Journal of Management*, 19(3), 707–724.

Drezner, N. D. (2018). Philanthropy mirroring: Exploring identity-based fundraising in higher education. *Journal of Higher Education*, 89(3), 262–293.

Fries-Britt, S., Cabrera, A., Kurban, E., & McGuire, D. (Under review. *A nuanced understanding of minority students' intentions and commitment to STEM*. Manuscript submitted for publication.

Hausman, L. R. M., Schofield, J. W., & Woods, R. L. (2007). Sense of belonging as a predictor of intent to persist among African American and white first-year college students. *Research in Higher Education*, 48, 803–839.

Hurtado, S., & Carter, D. F. (1997). Effects of college transition and perceptions of campus racial climate on Latino college students' sense of belonging. *Sociology of Education*, 70, 324–345.

Leonardelli, G. J., & Brewer, M. B. (2001). Minority and majority discrimination: When and why. *Journal of Experimental Social Psychology*, 37(6), 468–485.

Oyserman, D. (2009). Identity-based motivation: Implications for action-readiness, procedural-readiness, and consumer behavior. *Journal of Consumer Psychology*, 19(3), 250–260.

Spady, W. G. (1971). Dropouts from higher education: Toward an empirical model. *Interchange*, 2, 38–62.

Tajfel, H., & Turner, J. C, (1979). An integrative theory of intergroup conflict. In W. G. Austin & W. G. Austin (Eds.), The social psychology of intergroup relations (pp. 33–47). Chicago: Nelson-Hall.

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. University of Chicago Press, Chicago.

APPENDIX 3: STUDENT SURVEY

TEAM-UP Survey

Welcome to the AIP Task Force to Elevate the representation of African Americans in Undergraduate Physics & Astronomy (TEAM-UP) Survey.

This survey is designed to give the TEAM-UP task force insight into the experiences that affect the persistence of undergraduate African American students in physics and astronomy.

Please complete the survey and make your best estimate for each item. We know your time is valuable and we appreciate your sharing it with us. This survey should take no more than 15 minutes to complete.

Click here if you are returning to the survey from an earlier session.

If you have any questions or have problems with the questionnaire, contact Laura Merner of the Statistical Research Center of the American Institute of Physics at lmerner@aip.org or at 301-209-3066.

1) Have you ever taken an undergraduate physics course?
   - ◯ Yes
   - ◯ No, Exit Survey

2) Are you currently pursuing an undergraduate degree (AA / AS / BA / BS / AB)?
   - ◯ Yes
   - ◯ No, Exit Survey

3) Are you a….
   - ◯ Freshman
   - ◯ Sophomore
   - ◯ Junior
   - ◯ Senior

4) In what institution are you currently enrolled? Please fill in the name of your current institution.

5) What is your current or intended major?
   Astronomy or Astrophysics / Biology / Business / Chemistry / Computer Science / Economics / Education / Engineering/ English / Fine Arts / Foreign Languages / Geological Sciences / History / Mathematics / Music / Philosophy or Theology / Physics / Pre-medicine / Psychology / Social Science / Undeclared / Other:______________

6) How many college-level physics classes do you have credit for (successfully completed / AP credit)?
   Respondents may select one number from 0-20 in a drop down menu

7) Of these completed classes, how many are AP credits?
Respondents may select one number from 0-20 in a drop down menu

8) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree
Faculty/Instructors discuss career opportunities and/or jobs available with my degree.				
I feel confident that I could get full-time employment in my chosen field				

9) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree	N/A
I think about transferring to another institution					
I think about taking a break from studies to do something else (e.g., working, family responsibilities, traveling, etc.)					
I intend to leave my field after completing my degree					
I think about transferring to another major					
I intend to complete my major at my current institution					

10) I intend to apply for graduate school in physics or a related field. Please indicate your level of agreement with this statement:

Strongly agree	Agree	Disagree	Strongly disagree	N/A

11) Based on your overall college experience, how often are the following statements true for you. please answer the following questions to the best of your ability:

	Most of the time	Sometimes	Occasionally	Rarely	Never
I feel I am part of my academic department community					
I feel a sense of community with peers in my major					
I feel a sense of community with peers on my campus who share my ethnic/racial identity					
My department creates a supportive environment.					

12) Based on your overall physics experience, how often are the following statements true for you. please answer to the best of your ability:

	Most of the time	Sometimes	Occasionally	Rarely	Never
I feel confident I could do an excellent job on assignments in physics					
I feel confident I could do an excellent job on exams in physics					
I feel confident I can operate physics lab materials and equipment					

13) Based on your overall physics experience, how often are the following statements true for you. please answer to the best of your ability:

	Most of the time	Sometimes	Occasionally	Rarely	Never
Physics faculty/instructors encourage my participation in class					
Physics faculty/instructors are genuinely interested in my ideas and opinions					
I feel comfortable approaching my physics faculty/instructor for help when I don't understand a concept					
I personally have been treated negatively in my physics classes because of my race or ethnicity					
I have seen others treated negatively in my physics classes or labs because of their race or ethnicity.					

14) I personally have been treated negatively in my physics classes because of my other identities. Check all that apply.

- ◯ Gender
- ◯ National origin
- ◯ Sexual orientation
- ◯ Disability
- ◯ None of the above
- ◯ Prefer not to respond

15) Based on your overall physics experience, how often are the following statements true for you. please answer the following questions to the best of your ability:

	Most of the time	Sometimes	Rarely	Never	N/A
When I don't understand a concept discussed in my physics class/lab I seek out help from peers					
When I don't understand a concept discussed in my physics class/lab I seek out help from the main professor/instructor					
Physics faculty/instructors affirm my ability to do physics					
When I don't understand a concept discussed in my physics class/lab I seek out help from another instructor/mentor					
When I don't understand a concept discussed in my physics class/lab I search online resources for help (e.g. Khan academy, Physics classroom, YouTube, MIT online courses)					
I have felt socially-isolated in my physics classes or labs.					

16) Which of the following have been a source of discouragement in your physics courses or labs? Check all that apply.

- ◯ Course material
- ◯ Lab experiences
- ◯ Interactions with other students
- ◯ Interactions with faculty members
- ◯ Climate in the department
- ◯ I have not been discouraged in my physics classes or labs.

17) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree
I see myself as a scientist				
I believe others see me as a scientist				

18) I would be interested in working in the following areas. Check all that apply.
- ◯ Government lab
- ◯ University
- ◯ Industry
- ◯ Start my own business, entrepreneurship
- ◯ Non-governmental organization or non-profit organization
- ◯ K-12 school system (e.g., teacher)

19) I am being prepared to work in the following areas (check all that apply).
- ◯ Government lab
- ◯ University
- ◯ Industry
- ◯ Start my own business, entrepreneurship
- ◯ Non-governmental organization or non-profit organization
- ◯ K-12 school system (e.g., teacher)

20) I feel confident that I know what careers/jobs are open to physics graduates (or to my major). Please indicate your level of agreement with this statement.

Strongly agree	Agree	Disagree	Strongly disagree

21) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree
In addition to having a career, it is important for me to have a satisfying personal life				
It is important for me to be involved in organizations that promote the use of physics to improve society				
It is important for me to have a career that makes the world a better place				
It is important for me to apply my expertise in my major for the benefit of the community I belong to (e.g., racial/ethnic, religious, neighborhood)				
It is important to me to mentor others who want to study in my major				
My department supports me in the work that I want to do in my community				
I feel that the academic environment negatively impacts my well-being				

(These questions are only for physics majors)

22) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree
I feel confident majoring in physics is the right choice for me				
It is important for me to become a physicist				

(These questions are for all students)

23) What is your primary source of funding for school?
- ◯ Fellowship or scholarship
- ◯ Student job related to physics
- ◯ Student job not related to physics
- ◯ Government source (Pell grant, GI bill, etc)
- ◯ Off-campus job / Loan or debt you will repay
- ◯ personal savings / loan or debt your parents or family will pay
- ◯ Other: ________________________________

24) Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Disagree	Strongly disagree
I am concerned about paying for college				
Working to pay for college interferes with my studies				
I am concerned about how I would pay back my student debt once I graduate from college				
I am concerned about burdening my parents/ relatives with my college expenses				

25) On average, how many hours per week have you worked for pay over the last month?
I don't work for pay, 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55+

26) What is your gender identity?
Gender non-conforming / Man / Other / Woman / Prefer not to respond

27) What is your race/ethnicity? Check all that apply.
◯ American Indian or Alaska Native
◯ Black or African American
◯ Native Hawaiian or Other Pacific Islander
◯ Asian
◯ White
◯ Hispanic or Latino/Latina
◯ Other, please specify:
◯ Prefer not to respond

28) What is your country of origin?
Respondents may select their country from a drop down menu

29) Please indicate levels of formal education obtained by your mother/guardian. Check all that apply. STEM is defined as any discipline within science, technology, engineering or math.
◯ Grammar school or less
◯ Some high school
◯ High school graduate
◯ Some college education
◯ Associate degree in a STEM field
◯ Associate degree not in a STEM field
◯ College degree (Bachelor's or equivalent) in a STEM field
◯ College degree (Bachelor's or equivalent) not in a STEM field
◯ Some graduate education
◯ Graduate degree (e.g., MA, PhD) in a STEM field
◯ Graduate degree (e.g., MA, PhD) not in a STEM field
◯ Professional degree (e.g., JD, MD, MBA, etc.)

30) Please indicate levels of formal education obtained by your father/guardian. Check all that apply. STEM is defined as any discipline within science, technology, engineering or math.
- ◯ Grammar school or less
- ◯ Some high school
- ◯ High school graduate
- ◯ Some college education
- ◯ Associate degree in a STEM field
- ◯ Associate degree not in a STEM field
- ◯ College degree (Bachelor's or equivalent) in a STEM field
- ◯ College degree (Bachelor's or equivalent) not in a STEM field
- ◯ Some graduate education
- ◯ Graduate degree (e.g., MA, PhD) in a STEM field
- ◯ Graduate degree (e.g., MA, PhD) not in a STEM field
- ◯ Professional degree (e.g., JD, MD, MBA, etc.)

31) How did you decide upon your current major? If you are undecided, what do you think will help you decide?

32) What has helped you succeed in your undergraduate experience?

33) What has been a barrier to success in your undergraduate experience?

34) What is your current cumulative GPA?
- ◯ 0.0-1.99
- ◯ 2.0-2.49
- ◯ 2.5-3.49
- ◯ 3.5-3.99
- ◯ 4.0 or higher

35) What is your current cumulative GPA in your major?
- ◯ 0.0-1.99
- ◯ 2.0-2.49
- ◯ 2.5-3.49
- ◯ 3.5-3.99
- ◯ 4.0 or higher

36) Is there anything you'd like to tell us about your undergraduate experience?

37) Our research team will conduct interviews with a sample of respondents. Please provide your contact information if you would like to participate further in this research project.
Email: ____

Thank you for completing this survey and for helping to improve the experiences of African American students in physics and astronomy. Your participation is serving the scientific community.

If you would like to learn more about TEAM-UP, please visit www.aip.org/TEAMUP. If you have questions about the work of the task force, please contact Arlene Modeste Knowles, TEAM-UP Project Manager at 301-209-3164 or teamup@aip.org.

APPENDIX 4: DEPARTMENTAL SURVEY

TEAM-UP Survey

Welcome to the AIP Task Force to Elevate the representation of African-Americans in Undergraduate Physics & Astronomy (TEAM-UP) Departmental Survey.

This survey is designed to build departmental awareness around its structures, and provide the TEAM-UP task force insight into the institutional supports and structures that affect the persistence of undergraduate African-American students in physics and astronomy.

Please complete the survey for your department and make your best estimate for each item. It is suggested that someone with an in-depth knowledge of the department, such as the department chair or his/her designee, complete this survey. We know your time is valuable and we appreciate your taking the time to take a comprehensive view of the department and sharing it with us. This survey should take approximately 40 minutes to complete as there are some open-ended questions.

Your responses to questions will be saved as you complete the questionnaire. This provides you with the flexibility of returning to the survey to complete it at a later time. Just use the link provided in the original email and you will return to the survey. You can edit past answers if you wish.

Please complete the survey by August 15th 2018.

If you have any questions or have problems with the questionnaire, contact Patrick Mulvey of the Statistical Research Center of the American Institute of Physics at pmulvey@aip.org or at 301-209-3076.

1) Please complete the following:

   Your Name:

   Your Title:

   Your Institution:

   Your Email:

2) Which of the following degree types does your department offer:

   - ☐ Bachelors of Science (BS) in Physics
   - ☐ Bachelors of Arts (BA) in Physics
   - ☐ Bachelor’s Degree in Astronomy

3) Does your department offer any of the following degree focuses:
- ◯ Engineering Physics
- ◯ Applied Physics
- ◯ Astrophysics
- ◯ Biological, Medical or Health Physics
- ◯ Computational Physics
- ◯ High School Physics Teaching
- ◯ Other: _________________________

4) What percentage of your undergraduate physics students would you estimate typically participate in an undergraduate research experience (e.g. on campus, off campus, REU, co-op, internship, etc.):
______%

5) Compared to all students in your department, what percentage of your African-American students participate in undergraduate research

☐ Higher percentage ☐ Similar percentage ☐ Lower percentage

6) You indicated that the undergraduate research participation differed for your African American students as compared to all students. What do you think is the reason for this?

7) Does your department have a Society of Physics Students Chapter / Physics club?

☐ Yes ☐ No

8) What is your estimate of student participation in your SPS Chapter / Physics club activities?

☐ All / Most students participate ☐ Over half participate

☐ Less than half participate ☐ Few / No students participate

9) Compared to all students in your department, what percentage of your African American student participation in your SPS Chapter / Physics club activities?

☐ Higher percentage ☐ Similar percentage ☐ Lower percentage

10) You indicated that physics club participation differed for your African American students as compared to all students. What do you think is the reason for this?

11) Is there an established cost-free tutoring program / center in your department for physics students?

☐ Yes ☐ No

12) What is the overall usage of the tutoring resource?

☐ Constantly used ☐ Frequently used ☐ Occasionally used ☐ Infrequently used

13) What is the usage of your tutoring resource by your African American students?

☐ Constantly used ☐ Frequently used ☐ Occasionally used ☐ Infrequently used

14) Which of the following have you used in the past year to provide graduate school and career information to your undergraduates? (check all that apply)

◯ Alumni visits to the department
◯ Field trips to local industries
◯ The university career services office
◯ Departmental colloquia by physicists engaged in non-academic employment
◯ Departmental colloquia by physicists in academia
◯ Career materials from the Society of Physics Students
◯ Career materials from other professional societies
◯ Career materials from the American Institute of Physics
◯ Career seminar course
◯ Colloquia or workshops on graduate school opportunities
◯ Colloquia or workshops on the mechanics of applying to graduate schools
◯ Other (please explain)

15) Compared to all students in your department, what percentage of your African American students participate in or make use of the above activities / resources?

☐ Higher percentage ☐ Similar percentage ☐ Lower percentage

16) Does your department have a dedicated common area / workspace for undergraduate physics majors (like a student lounge)?

☐ Yes ☐ No

17) What is the overall usage of the undergraduate lounge space?

☐ Constantly used ☐ Frequently used ☐ Occasionally used ☐ Infrequently used

18) What is the usage of the undergraduate lounge space by your African American students?

☐ Constantly used ☐ Frequently used ☐ Occasionally used ☐ Infrequently used

19) Is there a separate gathering place that your African- American students are using to convene for the purpose of working on physics problems or to study?

☐ Yes ☐ No ☐ Don't know

20) Does your department provide building keys to undergraduate physics majors?

☐ Yes ☐ No

21) Which, if any, of the recruiting activities below does your department pursue? (please check all that apply)

- ◯ Actively recruit transfer students from two-year colleges
- ◯ Hold annual (or more often) departmental open house for prospective students and parents
- ◯ Host individual prospective students and their families to visit the department
- ◯ Hold summer workshops for high school students
- ◯ Faculty and/or students regularly visit local schools
- ◯ Identify enrolled students with potential to major in physics (e.g. from service courses)
- ◯ Other: specify

22) Does your department participate in a summer bridge program for incoming freshman or for transferring 2-year college students in an attempt to recruit underrepresented racial/ethnic students into your undergraduate program?

☐ Yes ☐ No

23) Please describe the type of program and how effective has this been in recruiting African American students?

24) Does your department engage in any recruiting efforts that specifically target underrepresented racial/ethnic groups in general and African Americans specifically?

☐ Yes ☐ No

25) Please elaborate on your targeted recruitment efforts:

26) How successful have these recruitment efforts been in bringing African American students into the department / major?

27) Does your department have a department-level committee(s) on diversity, equity, and/or inclusion?

☐ Yes ☐ No

28) Please describe the scope of the diversity, equity and/or inclusion committee(s) work:

29) Does your department participate in diversity and inclusion events, programs, conferences, or workshops?

☐ Yes ☐ No

30) Which of the following organizations or conferences have you been involved with in the last five years?
- ◯ National Society of Black Physicists (NSBP)
- ◯ National Society of Black Engineers (NSBE)
- ◯ Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS)
- ◯ American Physical Society (APS) National Mentoring Community (NMC)
- ◯ Conferences for Undergraduate Women in Physics (CUWiP)
- ◯ Conferences for Undergraduate Underrepresented Minorities in Physics (CUMiP)
- ◯ Other group or conference focused on diversity, specify ________________________________
- ◯ None of the above

31) Have you ever used any of the following resources to assess your department's climate?
- ◯ Using Belongingness Surveys (e.g. Walton et. al.)
- ◯ APS Committee on the Status of Women in Physics site visit (CSWP)
- ◯ APS Committee on Minorities site visit (COM)
- ◯ APS Bridge Program evaluation
- ◯ National Survey of Student Engagement (NSSE) Other, please specify:____________________
- ◯ We have not done a self-assessment of our climate.

32) Who has primary responsibility for advising physics majors?
- ◯ Several or all physics faculty members
- ◯ The department chair
- ◯ One physics faculty member (other than the department chair)
- ◯ A non-faculty physics department staff person
- ◯ University advisors outside the physics department
- ◯ Other, please describe _________________________________

33) On average, how often do most physics majors interact with their advisor(s)?

☐ Less than once per year ☐ Once per year ☐ Once per semester or quarter

☐ Several times per semester or quarter

34) Does your department have a formal or informal mentoring program for undergraduates?

☐ Yes ☐ No

35) Please describe who is involved and how your mentoring program for undergraduates is structured:

36) Is there a specific mentoring program or initiative aimed at retaining students from underrepresented racial/ethnic groups?

☐ Yes ☐ No

37) How is the mentoring program for underrepresented groups different from the general mentoring program?

38) How effective do you think this mentoring program has been at retaining African American students?

39) Does your department engage in explicit retention efforts for your undergraduate physics students?

☐ Yes ☐ No

40) Please describe your undergraduate student retention efforts:

41) Do you have retention efforts specifically for African- American students in your department?

☐ Yes ☐ No

42) How do these retention efforts for African Americans differ from your general department retention efforts?

43) Does your department or institution track the student completion rates of introductory physics courses that may lead to a physics bachelor's degree?

☐ Yes ☐ No

44) Do you know the demographics of the students enrolled in your introductory physics courses that may lead to a physics bachelor's degree?

☐ Yes ☐ No

45) Do you know the proportion of students who enroll in your introductory physics courses that successfully complete the course by race?

☐ Yes ☐ No

46) Estimate the proportion of students who successfully complete your introductory physics courses that may lead to a physics bachelor's degree (last three years combined):

____% of all students successfully completing the course

_____% of African American students successfully completing the course

47) Do you know the proportion of students who declare physics as a major who successfully receive the degree within 6 years?

☐ Yes ☐ No

48) Estimate the proportion of our declared physics majors who successfully receive the degrees within 6 years (last three years combined):

_____% of all declared majors who successfully receive a physics degree

_____% of African American declared majors who successfully receive a physics degree

49) What type of information does your department currently maintain on its alumni? (check all that apply)
- ◯ Information on employment or graduate school plans at the time of graduation
- ◯ Mailing or email addresses for students at the time they graduate
- ◯ Annual updates from past students by email or phone
- ◯ Mailing list for departmental newsletter
- ◯ Surveys of alumni
- ◯ Other: Please specify______________________________

50) Do you have other activities or resources in your department to enhance your undergraduate program that have not been asked about?

☐ Yes ☐ No

51) What other activities or resources in your department enhance your undergraduate program for all students?

52) What other activities or resources in your department enhance your undergraduate program specifically for African American students?

53) Overall, which activities, programs, or resources do you consider the most effective in recruiting or retaining African- American students in your department?

54) If you had unlimited resources, what do you think would be an effective practice for recruiting and/or retaining African American undergraduate physics majors?

Thank you for completing this survey and for helping to improve the experiences of African American students in physics and astronomy. Your participation is serving the scientific community.

If you would like to learn more about TEAM-UP, please visit www.aip.org/TEAMUP. If you have questions about the work of the task force, please contact Arlene Modeste Knowles, TEAM- UP Project Manager at 301-209-3164 or teamup@aip.org.

APPENDIX 5: SITE VISITS TO IDENTIFY SUCCESSFUL DEPARTMENTAL PRACTICES

The AIP charge to this task force was to "draw lessons from programs that have been successful in recruiting and retaining undergraduates in physics from traditionally underrepresented racial/ethnic groups." We sought to carry this out by learning from physics departments that had succeeded in graduating significant numbers of African Americans with bachelor's degrees, as well as those departments that were intentionally striving to enhance the success of underrepresented students by having funded programs supporting this goal. Our research activity had two parts.

The first part was a survey instrument (Appendix 4) sent to the chairs of 79 departments that had expressed interest in the TEAM-UP project or were among the top bachelor's degree producers for African American students. The survey inquired about departmental practices and provided information that we used both to select departments for more information and to guide our set of topics to explore with those departments. We received 40 complete responses.

The second part consisted of one-day site visits to a set of the most successful departments across a range of institutional types. As with the SPIN-UP project (Hilborn, Howes, and Krane 2003), we examined highly successful departments to learn what distinguishes them from other departments. Focusing on outcomes for African American students yielded a subset of physics departments different from what we would get if considering success outcomes for all students.

Table 1 shows the list of top-producing departments for African American physics bachelor's degrees during the five-year period ending June 30, 2017 (data from IPEDS). Only the top five Historically Black Colleges and Universities (HBCUs) are included; the top nine degree producers, and 11 of the top 12, are HBCUs. (During this period, 30% of all physics bachelor's degrees awarded to African American students nationwide were granted by 30 HBCUs out of 775 total departments.) After the HBCUs, the table lists the top five non-HBCU departments by degree production. PBI denotes a Predominantly Black Institution (an institution with greater than 40% black enrollment), and PWI denotes a Predominantly White Institution. Finally, a small department at a state university with a relatively high percentage of degrees going to African American students is listed (Henderson State University). The top two astronomy departments are also listed. Highest degree designation and degree counts include only physics and astronomy. The numbers for African American students exclude students who are multiracial or for whom race and ethnicity are unknown; therefore, these data slightly undercount the numbers of degrees to African Americans.

Institution Physics Departments	School type, highest degree	Afr. Am. BS 2013–17	Total BS 2013–17
Morehouse College	HBCU, Men, BS	32	36
Alabama A&M University	HBCU, PhD	20	23
Dillard University	HBCU, BS	19	21
Xavier University of Louisiana	HBCU, BS	18	22
Hampton University	HBCU, PhD	17	19
. . .	. . .	. . .	. . .
Georgia State University	PBI, PhD	14	91
MIT	PWI, PhD	12	424
Chicago State University	PBI, BS	11	15
Southern Arkansas University	PWI, BS	11	84
University of Maryland College Park	PWI, PhD	11	305
. . .	. . .	. . .	. . .
Henderson State University	PWI, BS	3	23
Astronomy Departments			
Columbia University	PWI, PhD	4	44
University of California Santa Cruz	PWI, PhD	4	82
Source: IPEDS Completions, National Center for Education Statistics			

Table 1: Top Producers of Physics and Astronomy Bachelor's Degrees to Black or African American Students

After reviewing the degree completion data and departmental survey responses, we identified a set of departments spanning different institution types, sizes, and geographic locations as candidates for site visits. In total, we visited five institutions: one HBCU (Morehouse), two PBIs (Chicago State and Georgia State), and two PWIs (University of Maryland and Henderson State University). At the outset we decided to visit both primarily black-serving institutions (HBCUs and PBIs) and PWIs. Our selection process considered both the total number of African American physics bachelor's degrees awarded and the fraction of all physics bachelor's degrees that were awarded to African American students. The latter criterion was important to ensure that for PWIs we did not visit only the largest departments. We also considered the departmental practices described in the surveys, in order to increase the likelihood that we would learn about promising approaches for enhancing the success of African American students.

Although we did not visit any astronomy departments, several of the departments we visited included both physics and astronomy, and we spoke with students studying in both fields. Summaries of all five site visits are given in Appendix 6.

In advance of each site visit we contacted the department chair to describe our protocol and obtain their consent via a contract (Appendix 7). The chair then arranged an itinerary that included meetings with key faculty, administrators, and students. We communicated our goal to learn from the department's success in graduating African American bachelor's degree students and indicated that we would produce and share with the department a summary of the positive things we learned. If we heard any criticism, it would be kept confidential and discussed only in a way that would not identify the institution. In the end, the visits were overwhelmingly positive, and we learned a great deal that inspired us and informs our recommendations.

Each site visit involved three members of TEAM-UP who spent a full day meeting with faculty, staff, and students to learn about departmental programs and the student experience. We sought information on each topic in the left-hand column of Table 2. Initially we identified the first seven topics, but quickly we realized the need to broaden our investigation to include holistic support (often from outside the department) and the culture of physics as reflected by departmental customs and norms.

Faculty-centered view	Student-centered view
Recruitment	[High-school experience, gateway courses][5]
Curriculum	Academic capital
Cocurricular activities	Welcoming and supportive culture
Advising/mentoring	Academic advising, mental health, financial concerns, career prospects
Research	Physics identity
Retention programs	[College or university offices, supportive staff]
Climate/belonging	Imposter syndrome, stereotype threat, sense of belonging
Holistic support	Intersectionality, mental health, bringing one's whole self
Physics customs and norms	Physics culture

Table 2: Thematic Areas for Faculty and Students From Site Visits

Under recruitment, we asked about how students entered the major. In many institutions, no special effort is made to recruit physics majors (as recruitment is handled at the institutional level); in some, outreach efforts are made to local communities. The curriculum is largely similar across departments, with the exception that some departments, like Morehouse's, offer a physics track designed for engineers, notably those participating in its Dual Degree Engineering Program. In cocurricular activities, we found widespread involvement with the Society of Physics Students (SPS) and other student clubs. Retention programs include tutoring centers as well as academic excellence programs such as honors college programs. We also sought the perspectives of senior administrators such as the dean and provost. When they were available, their views were very helpful, especially in showing how the department's efforts related to those across the institution.

Our site visit teams began with a faculty-centered framing of major theme areas for physics departments (left column of Table 2). We quickly discovered—from both students and faculty—that the most important themes relevant to the departments' success were those in the right-hand column. These are broadly similar to the themes and student experiences that emerged from the TEAM-UP survey subcommittee's analysis of its student survey and interviews (Appendix 2). In the end, for purposes of this report, we condensed these themes into the five identified in the Executive Summary: Belonging, Physics Identity, Academic Support, Personal Support, and Leadership and Structures. Our thinking was further informed by findings from the research literature on success of African American students in physics (or, more broadly, in STEM) compiled by our literature review subcommittee.

[5] The bracketed items were not listed in the survey subcommittee's version of this table.

The site visits revealed a set of common factors associated with successful outcomes for African American students:

1. Top-performing departments consistently have multiple faculty members who are effective mentors and make the students feel they care about them as individuals. These faculty include those who are not members of marginalized groups (e.g., White men).
2. Leadership by a committed department chair is crucial to communicating department norms and values (defining the culture), hiring supportive faculty, and giving these faculty support and encouragement in their efforts to promote the success of African American students.
3. Students' physics identity is strengthened by research, and this helps students to persist.
4. Students' sense of belonging is strengthened by having peers and more advanced students of similar social identity (race, ethnicity, gender) in the department, and this helps students to persist.
5. Institutional programs such as college-level advising, emergency financial aid, and mental health counseling provide additional crucial support. They also help set institutional norms and values that can help sustain department efforts through leadership transitions.

These findings are described in more detail in Supporting Student Success.

APPENDIX 6: SITE VISIT SUMMARIES

Chicago State University

Institutional and Departmental Profile

Chicago State University (CSU), located in Chicago, is a public, comprehensive university. Classified as a Predominantly Black Institution, it was founded in 1867 and has an enrollment of about 3,100 students. There are currently 18 physics majors, of which about half are women. The physics degree program is in the combined Department of Chemistry, Physics, and Engineering Studies and is housed within the College of Arts and Sciences. IPEDS reports Chicago State as the third-largest producer of physics bachelor's degrees to African Americans, excluding HBCUs.

The department's success arises from (1) caring faculty who develop personal mentoring relationships and recognize different student needs; (2) the absence of deficit-based thinking—faculty develop students' strengths, noting that "Our students are our strength"; (3) the Learning Assistants program and a strong emphasis on undergraduate research through the Center for STEM Education and Research to facilitate student-faculty engagement; (4) regional, national, and international collaboration through the Illinois Louis Stokes Alliance for Minority Participation and the Learning Assistant Alliance; (5) a strong record of grants that target undergraduate research participation; and (6) a focus on faculty collaboration within and across disciplines. The mutual support and strong commitment of all physics faculty reduces the burnout associated with singular champions and allows the department to remain strong through financial turbulence. It also provides a model of caring and cooperation that students emulate.

Perspective of Department Chair, Faculty, & Staff

Recruitment & Retention

The majority of students (70%) are transfers from community colleges. Many transfers are older, nontraditional students. The focal point of first-year advising is the Student Union, where a professional adviser works with students the week before classes start. This central office has good connections with the department chair, and students are also connected with a faculty adviser.

The introductory physics and engineering classes provide a good recruiting opportunity for the major. Students are drawn by the possibility of visiting the LHC at CERN. Successful alumni are invited to speak with students. Additionally, the National Society of Black Physicists (NSBP) conference has inspired some students to become laser-focused on research excellence. Faculty run the Learning Assistants (LA) program which provides support to students in introductory classes. By participating as LAs, students join a learning community and develop a strong physics identity.

Curriculum

Many of the incoming students are not ready for calculus. Although the Physics 1 course is calculus-based, the department provides students pathways to entering the major that begin with chemistry or engineering, which require algebra rather than calculus. Most students declare a major at or soon after matriculation.

The major requires 100 hours of directed research and a thesis. As an example of ways in which they promote the professional development of students, faculty are now tailoring the students' thesis studies to be published in the *SPS Journal on Undergraduate Research in Physics*.

Cocurricular Activities and Resources

The department chair emphasized the importance of undergraduate research to student engagement and retention. Some tuition support is provided through the National Science Foundation-funded S-STEM program. Students have reported that it would help more to have direct stipend support because it would reduce the amount of time they have to work off-campus. The collaboration between physics and chemistry is important to the success of special programs. Collaboration distributes the workload and allows for cross teaching based on specific faculty expertise. Moreover, students are aware that they are part of a larger community, which helps build critical mass for peer and faculty support.

The Center for STEM Education and Research provides funding for student research and conference travel. Because many students are commuters and not available after hours, club meetings are held during a period with no classes. Students have a dedicated lounge in the Williams Science Center and also utilize a classroom as a study space. Faculty noted that many students are nontraditional with a variety of competing responsibilities. To build community, the faculty encourage students to study together in the Science Center rather than working alone. Faculty provide students with support, advice, and coaching and refer students to professional counselors when appropriate.

Climate and Belonging

The Learning Assistants program and undergraduate research provide a scaffolding to help faculty develop personal connections with students. Chicago State has hosted three regional conferences for Learning Assistants, two of them being with community colleges. The two faculty members who run the LA program are both White, while almost all of their students are Black. They are sensitive to race and class and find that listening to their students is crucial to navigating cultural dynamics. One faculty member noted, “Students are the greatest experts in their own experience.” Faculty spoke passionately about their care for the students; this is reflected in a series of quotes: “You have to set high expectations of students, be realistic about where they are, then take them where they can be.” “These are the most talented students anyone could want.” “Building community takes a lot of sweat equity.” “When you know someone, you look out for them.” The collegiality and unity of mission of these faculty were extraordinary.

Perspective of Administration (Office of the Dean, Office of the Provost)

Recruitment & Retention

The provost noted that Chicago State has reached out to the Chicago Public Schools (CPS) system to help it revamp its curricula in chemistry, physics, and biology. Faculty are advising CPS and will work with teachers in the implementation. The dean noted the strong care for students provided by all faculty including the general education instructors. The department maintains a tutoring center in the library with LAs to help with retention. Also at Chicago State, an early academic warning system is utilized for every undergraduate subject, so that students who are falling behind are quickly contacted by academic support staff, advisers, and instructors. Chicago State aspires to replicate the centralized system pioneered at Georgia State University.

Curriculum

The college provides faculty development and release time for research with students and for recipients of grants, which enrich the curriculum. There is a two-day onboarding process for new faculty, with workshops offered by the Center for Teaching & Research Excellence that emphasize active learning and personalized instruction, including the use of LAs.

Since there is no graduate program in physics, the faculty bring their undergraduates into their research groups. CSU students persist and go to graduate school at higher rates than do students at PWIs. Of the last 11 physics graduates (2015–2018), 6 have gone straight to graduate school. Other important factors in success are the hiring of faculty who fit the "culture of caring" for students, and strong faculty collaboration across disciplines.

Cocurricular Activities and Resources (CSER, ILSAMP, and OGRA) [6]

Faculty who come from different scientific disciplines operate in a highly collaborative fashion to provide research opportunities for students through various on-campus programmatic offices. This holistic approach to engaging undergraduates in research and education makes it easy for students to navigate the system. One of the programs manages the detailed logistics (passports, airfare, etc.) that make international student travel possible. The importance of providing stipends, not merely tuition support, to students with extensive financial needs is recognized by the special program leads. Finally, students participate in outreach, including to high schools in the Chicago Public Schools system.

The site visit committee was impressed with the range of activities pursued by these campus programs and the strongly collaborative nature of the work across departments to effectively engage students. When asked how they managed to be so successful in receiving grant funding, the faculty credited the experience of the senior faculty and the support of the Chicago State administration in providing 50% release time for a faculty member to work with OGRA. The farsighted and collaborative model of integrating research and education at Chicago State is a significant factor in the school's success in graduating African American physics bachelor's degrees. In addition, many faculty members rotate through administrative roles at Chicago State so they learn how to work effectively with their local administration.

Climate and Belonging

Commenting on the school's nontraditional students, the provost noted that "many students come here for second chances." Indeed, even though few students reside on campus, Chicago State provides an academic and social/emotional home for its nonresidential, nontraditional students.

Perspective of Students

Recruitment & Retention

The first-year experience, including advising, is run by the Student Union. This program forms cohorts of students who meet with a college adviser. The college adviser then connects them with faculty advisers in the relevant department. Students described the physics adviser and other faculty as being very committed to their well-being and success. They especially noted that faculty members mentor and guide them regarding

---

[6] Center for STEM Education and Research (CSER), Illinois Louis Stokes Alliance for Minority Participation (ILSAMP), Office of Grants and Research Administration (OGRA).

presenting at conferences and further noted that this has increased their confidence and self-efficacy. As well, the senior students become leaders and role models for newer students, providing advice and guidance about curriculum, coursework, and faculty.

Cocurricular Activities and Resources

Students noted the importance of both financial and personal support from Chicago State, including stipend support as well as moral support during moments of family crisis. Students praised the LA program as helping them to learn the subject material better, and one appreciated collaborating with faculty on lesson plans, noting that it increased the student's level of professionalism.

Students praised the support department faculty gave to students during the campus financial crisis of 2015–17. Students were given time in at least one class to talk about the impact the budget crisis had on them. Overall, the faculty attempted to keep students focused on research and learning, allaying fears and reassuring them that faculty members would do all they could to help them succeed.

Conference attendance and student organizations and clubs, such as the Honors College, SPS, NSBP, and the National Society of Black Engineers (NSBE), enhance the strong community provided by the physics program. Participation in organizations helps students to develop leadership and time-management skills and provides near-peer role models. Through such support, students develop professional identity and persistence to succeed in research and, eventually, graduate education.

Climate and Belonging

Students highlighted the supportive family atmosphere of the department and the key role of undergraduate research. The students noted that physics faculty help them feel capable. Their care extends beyond the classroom and is not typical of every department. Even if classes are lecture based, the faculty often break the students into subgroups to collaborate. Faculty help students one-on-one both inside and outside the classroom.

The students also found support in other students. Physics students are very community minded, socializing with other STEM students and going to one another's events. In 2016 a major freeway was shut down by physics students protesting the lack of a state budget for Chicago State.

The students described a ritual that gives a sense of the inner strength and connection to the South Side of Chicago. An old railroad boxcar was the first classroom on campus when newly freed slaves began attending classes in 1867. Now Chicago State students touch the boxcar on matriculation and do not touch it again until they graduate.

Georgia State University

Institutional and Departmental Profile

Georgia State University (GSU) comprises seven campuses throughout the metro Atlanta area and has an enrollment of over 51,000 students. GSU is both a doctorate-granting university with very high research activity and a predominantly Black institution, with an undergraduate enrollment that is more than 40% Black or African American. Also, 58% of its students are low income (defined by Pell Grant eligibility), and 25% are first-generation to college. The university is well known for its elimination of graduation gaps through the extensive use of predictive analytics, academic support, and financial support to assist students before they go off track. Over the past four years, African American, Hispanic, first-generation, and Pell-eligible students have, on average, all graduated from GSU at or above the rate of the student body overall—making GSU the only public university in the nation to attain this goal. Excluding HBCUs, GSU graduates the most African Americans in physics (14 during the five-year period 2012–17, or 15% of all GSU physics graduates).

The site visit identified several key ingredients for the department's successes: (1) the associate chair is a champion for students with a strong understanding of pedagogy and student development; (2) the university as a whole and the College of Arts and Sciences (CAS) provide strong support for all students; (3) there is effective departmental advising of majors; (4) the department emphasizes research and prepares students for it with an introductory class (PHYS 1000), junior-level lab (PHYS3300), and senior capstone (PHYS 4900); (5) multiple pathways into the physics major make it relatively easy for students to enter from other disciplines; (6) students are drawn to physics by popular general education classes in astronomy; and (7) information about the career benefits of a physics degree is disseminated early and often.

Perspective of Department Chair, Faculty, & Staff

Recruitment & Retention

The faculty do not actively recruit students into physics; the students are drawn in by peers and by inspiring physics instructors. Faculty emphasized the importance of curricular flexibility—"Students commute, they work, their life is messy"—concluding that it is important to remove barriers for students.

The number of physics graduates has increased from 3 or 4 per year (on average) during the early 2000s to about 7 per year in the late 2000s and 20 per year (more recently). As the numbers grew, so did the diversity: the fraction of physics bachelor's degrees going to women and to African Americans increased from roughly 10% to 20% for each of those demographics. The university has a unique three-level, overlapping advising system composed of the central university's Advisement Center, college-level advising, and departmental faculty advisers. Students who are not ready for calculus-based physics can catch up with summer math classes, and they also benefit from multiple tracks into the major. The department offers a two-hour-per-week first-year seminar called "Gateway to Physics" (PHYS 1000). This class prepares students for the intellectual environment of research, provides information about physics careers, and helps students develop study skills.

Curriculum

The following curricular elements are important for driving the increasing numbers of majors:

1. The major was streamlined, and multiple pathways to the degree were highlighted.
2. The "Gateway" class helps students develop a sense of belonging to the major.
3. Junior- and senior-level research classes (PHYS 3300 and 4900) involve students in ongoing research and inform them about physics career opportunities.

The capstone class, PHYS 4900, was expanded from 1 to 3 credit hours. Students in this class write proposals, do research, write reports, and give oral presentations, and they learn about careers in physics.

Undergraduate research is very helpful for drawing students into the physics major. There is now a calculus-based astronomy class with hands-on observing at the GSU observatory 60 miles east of Atlanta.

The faculty we spoke with were all committed to undergraduate teaching. Several have taught astronomy. Others teach the algebra-based PHYS 1111/1112 or calculus-based 2211/2212 introductory sequences, which utilize studio physics pedagogy with peer instruction.

Cocurricular Activities and Resources

An SPS study room is provided for physics majors. At one time SPS organized tutoring for undergraduates. More recently, the university funds a STEM Tutoring Center. A faculty member recruits advanced physics students to serve as tutors in this center.

Climate and Belonging

The teacher preparation program within the physics major has sensitized faculty to the broad range of student needs.

The faculty noted that Black students are present in significant numbers throughout the physics sequence. The introductory PHYS 1000 is very important for building a sense of belonging. The common rooms (SPS and a separate astronomy room) provide valuable space for peer connections. Generally, students have not been observed to segregate themselves by race.

Staff members remarked that the astronomy faculty "work together very well." This collegiality extends to the students. The senior administration of GSU sends a clear signal that recruiting and academic success of underrepresented minorities is important. Raising thoughts on how the department could do even better, one faculty member mentioned recruiting underrepresented minority faculty members.

Perspective of Administration (Office of the Dean and Office of Academic Success)

Recruitment & Retention

Administrators described the advising system, including its special intrusive features, that Georgia State has implemented for all students. They also highlighted their close connections with a particular physics faculty member who has been interactively working on implementation of intrusive advising within the department.

A central Advisement Center has five advisers for all the STEM students, and they meet with each student once per year. Summaries of each advising meeting are recorded in the university-wide Navigate software system designed by the outside firm EAB as part of the university-wide student success management system.

These summaries are available to the college-level adviser and a department-level adviser. The Navigate system also tracks student progress on assignments, attendance, and exams in key classes. Performance data are used for the university-wide academic alert system. The CAS then requires meetings between advisers and students when needed.

The STEM Tutoring Center consolidated independent department-level efforts in a nice new space. Students enter the Tutoring Center by swiping their ID cards, and these entries are recorded into the Navigate system. There is a university-wide Center for Excellence in Teaching and Learning (CETL) that offers training for faculty and graduate teaching assistants.

Curriculum

Incoming first-year students are encouraged but not required to attend a new-student orientation. First-year students participate in first-year learning communities (FLCs) and can opt out, but most participate. Each FLC has 25 students who are interested in one of several broad areas called meta-majors; STEM is one of these meta-majors. Each FLC has an adviser from the university's central Advisement Center.

Cocurricular Activities and Resources

The college has a Mentoring Working Group that focuses on graduate student mentoring as part of a CAS strategic plan. The central university's strategic plan places education and diversity at the top of its priorities. There also exists a Center for Advancement of Students and Alumni, which helps students transition to graduate school in STEM fields.

Perspective of Students

Recruitment & Retention

Not only are nearly 60% of Georgia State students low income (Pell eligible), but many students work more than 30 hours per week. Of the students interviewed, most work outside GSU and up to 40 hours per week. Several of those interviewed came from Perimeter College (a two-year college partnering with GSU) and were drawn into physics by inspiring classes at GSU. Only one of those interviewed began as a first-time student at GSU. Several were older and described themselves as returning students. The diversity of this group illustrated the value of the physics curriculum's flexibility and multiple pathways to the degree.

Cocurricular Activities and Resources

The resources most used by the students who met with the site visit team were the STEM Tutoring Center (at least two of the students were tutors) and the AIP/SPS Careers Toolbox.

When asked about their sources of support and persistence, the students said they study from the textbooks or YouTube videos and rely on one another, communicating by mobile phone or GroupMe text messaging. Several students have a long commute and/or work long hours so they tend to study alone.

Students appreciate the SPS study room and the test preparation discussions that take place there. More advanced students help younger students there as well as in the Tutoring Center. All reported that they struggle with the difficulties of the major and find their peers helpful. These students also reported that they see benefit in helping and teaching one another. "The best way to learn something is to teach it," one noted. Similarly, the Women in Physics group provides undergraduates with mentoring by graduate women. This group hosts an Atlanta-area Women in STEM conference, now in its fourth year.

Climate and Belonging

The students noted that the major is relatively small and that they get to know one another, bonding around physics but not so much around social life, given the outside demands on their time. Several were active in student clubs including SPS and the astronomy club. They indicated that White students, international students, and students of color in physics all got along well. One student noted, “When I did my advanced physics lab and half the students were Black, it just blew me away.” Diversity is natural and appreciated at GSU. This student remarked that people don’t talk about race because “you don’t feel alone . . . you also feel connected.” Several students commented on how welcoming GSU was. Students also expressed feeling comfortable because they had peers of similar backgrounds.

These students felt a sense of belonging in the major. “Anyone can be [a physicist] if you have the mind-set to learn, to understand the way things are.” However, they felt that the title *physicist* is “more professional” and suggested that using it means getting a PhD. One said, “It’s weird to call yourself a physicist. I look at my professors, and… I don’t see myself as them.” Most of the students who met with the site visit team plan to go into industry rather than academia.

Henderson State University

Institutional and Departmental Profile

Henderson State University, a small, state-funded, liberal arts institution located in Arkadelphia, Arkansas, was founded in 1890. Henderson has an enrollment of about 3,400 undergraduates. In fall of 2015, Henderson was ranked fifth in the nation in the percentage of graduates who went on to graduate or professional school within one year of graduation. The physics program is part of the Engineering and Physics Department within the College of Arts and Sciences.

During a 21-year time frame, the physics department has had 16% African American and 15% women graduates (national averages for bachelor's degrees awarded in 2016–2017 were 3.1% and 20.5%, respectively). The success of Henderson State University in graduating African American physics majors is based on a combination of practices implemented by caring faculty. Every undergraduate student participates in a faculty-guided research project; the SPS chapter is very active and engaging; and students are actively involved with the community through the rocket club and the school's observatory, which hosts school group tours. The advisement process is superb and includes a thorough early-alert contacting procedure with alternative methods of student support. The Office of Student Affairs and Student Success plays an essential part in creating a sense of belonging by supporting and promoting the Society of Physics Students (SPS), Science Olympics, American Society for Engineering Education (ASEE), and other student clubs and activities that serve the extended community and create a network of support.

Perspective of Department Chair, Faculty, & Staff

Recruitment & Retention

Many of the physics majors are recruits from the math and aviation departments (aviation majors must have a physics minor). There are approximately four to eight physics graduates per year.

To assist with retention, the faculty provide advisement, academic support, opportunities for research, and involvement with the larger physics community through SPS. Mentoring also occurs through interactions with visiting alumni. There is a mandatory initial fall meeting where students learn about requirements, resources, clubs, undergrad research, and ongoing projects.

Curriculum

There are two tracks for physics majors, a traditional track and another for teacher certification. The department works hard to ensure that each student gets through the early courses in the curriculum and encourages them to join the SPS and ASEE clubs while still in those courses in order to build engagement.

The overall approach of faculty is to meet students where they are, work with them academically, and help students with issues outside of class. Faculty are caring and show students that they matter. The department manually tracks students' progress. This tracking can trigger an early alert, which includes emailing instructors and connecting the student with resources (career resources, mental health resources, etc.). The department works hard to ensure that each student gets through pre-math courses.

Cocurricular Activities and Resources

The department uses the AIP/SPS Careers Toolbox to advise students who are not aware of what career opportunities exist for those with a physics degree. Additionally, physics alumni return to discuss their careers, and connections with alumni also occur via web talks, site visits, and job shadowing. The SPS chapter is a joint chapter with Ouachita Baptist University, which is across the street from Henderson State. The chapter is very active and engages in research activities, competitions, and annual field trips (e.g., to NASA or research conferences). Henderson State regularly receives SPS Outstanding Chapter recognition. The department has the National Association of Rocketry Section 77 Rocket Club, which includes members of the community. Additionally, Henderson State has a McNair Scholars program and an Upward Bound program that provides support to underrepresented and first-generation students.

Climate and Belonging

Henderson's core values include "Human Value and Differences," "Collaboration and Community," "Integrity," and "Students and Student Success." The university's core values guide the physics and engineering department, and this is evident in the designated space for physics and engineering students to study and do homework, collaborate on research projects, conduct SPS meetings, and support one another.

The department chair and faculty work together to ensure that students are involved in the department-sponsored clubs, engaged in scholarly activities, communicating with mentors, and interacting with other physics and engineering students on a local and national level.

Perspective of Administration (Office of the Provost, Office of the Dean, Office of Student Affairs, and Office of Academic Services)

Recruitment & Retention

First-generation, economically disadvantaged, nontraditional, and working students represent many of the students at Henderson. Sixty percent of students are first-generation, and 42% receive Pell grants. Transfer students make up 7% in total. Funding from the state is based on retention through a formula set at the state level. In addition, the Higher Learning Commission has requirements for persistence and completion for the university college program. Seven professional advisers, which include one for the sciences and one for at-risk students, are a part of Henderson State's Reddie Intervention for Success in Education (R.I.S.E.) program. The R.I.S.E. program serves students who are first-generation to college or who are admitted to the university with a low ACT score.

Each Henderson student has a department adviser and a professional adviser. First-year students meet with an adviser several times throughout the year; students are encouraged, but not mandated, to visit faculty advisers in their department after they have successfully completed 30–35 credit hours. Free tutoring for all students is offered through the Office of Academic Services.

Curriculum

Henderson Seminar is a first-year experience designed to help students understand how to be successful and how to handle debt. There is a comprehensive process for advising at-risk students that includes contact by email, phone call, Google Voice, and text. The alert system includes referral to further resources and will dispatch counselors to residence halls to meet with students (if needed).

A Summer Bridge program targets underserved students and focuses on math preparation. Since students must be in calculus in order to enter University Physics I, this Summer Bridge program provides a possible pathway to prepare students for physics.

The provost expressed the importance of high-quality teaching. Seventy-six percent of faculty are tenured or tenure track (meaning that few adjuncts are teaching courses). Research publication and funding count little for tenure; faculty are evaluated primarily on the basis of teaching. Still, many faculty members have published books—with nearly three dozen published since the current provost arrived.

Physics (and engineering) graduates are successful and finish in high numbers because of faculty engagement. Hands-on experience in the laboratory is very important, and undergraduates are allowed to work directly with sophisticated laboratory instrumentation.

The Center for Teaching and Learning offers some faculty professional development and advises the provost on faculty needs. There exists travel support for faculty to attend the AAPT New Faculty Workshop. There are also grants providing release time for faculty development. The university offers workload reassignment and typical support for faculty research and development as well as funding for travel expenses that would be expected at the college and university level.

Cocurricular Activities and Resources

Henderson State University is a part of a space grant consortium consisting of all the four-year colleges in Arkansas. This grant supports student research and travel to a NASA facility. Student research is also supported and highlighted through an annual undergraduate research conference, hosted at Henderson State, that is open to all Arkansas universities and colleges. The Office of Student Affairs has funding that student clubs and organizations can request through an application process to support activities.

When students need financial assistance, there are options to help them, including a payment plan, an emergency fund to cover tuition if they are within eight hours of completion of the degree, and a Final Mile scholarship pool). Some physics majors are in the honors college and receive other forms of support (housing in the Honors College, separate first-year curriculum, and merit-based scholarships).

Climate and Belonging

The Office of Student Affairs makes a conscientious effort to create and support programming that is inclusive and encourages student success. Support for students of color comes from others who are not necessarily in the same department. The Office of the Dean believes that communicating the college's focus on an inclusive learning environment has a big influence on student success. During the graduation ceremony, first-generation students and faculty are recognized. In addition, there is a tradition that involves faculty giving a charge and a preselected student providing a response. The student response includes an acknowledgment of what worked and helped them through college.

Henderson State values collaboration and creates an environment where everyone's voice can be heard. This is consistently seen through initiatives such as the monthly Coffee and Conversation, where faculty, staff, and students are invited to tackle topics such as gun violence or immigration. Such issues affect students in various ways, and it is important that the campus community show it can acknowledge and discuss them.

Perspective of Students

Recruitment & Retention

Students prefer that faculty advisers in their department help with registration issues, instead of central advising. Mentoring appears to happen organically among peers within the dedicated space of the physics club room.

Cocurricular Activities and Resources

All of the students expressed excitement about research. Three students were planning to travel to Washington, D.C., for the Council for Undergraduate Research "Posters on the Hill 2019" event. Students had participated in this event in the past.

Climate and Belonging

From the students, it was clear that SPS plays a big part in creating a sense of belonging. The students all shared that in SPS they find encouragement, academic support, and a common bond beyond the classroom. One student stated that he joined SPS to spend more time in an environment where he can get help. He went on to say that the dedicated space encourages group involvement, which helps students stay on track. It is evident that a sense of community comes out of friendships made via the dedicated space and other cocurricular activities.

Morehouse College

Institutional and Departmental Profile

Morehouse College, a private institution located in Atlanta, was founded in 1867, and physics degrees were first offered in 1942. It is the only four-year liberal arts HBCU that is all male, and it has an enrollment of about 2,200 students. The Department of Physics & Dual-Degree Engineering is administratively located within the Division of Science & Mathematics.[7] There are about 25 pure physics majors and 150 pre-engineering majors. The department has seven full-time faculty and two adjunct faculty and offers three B.S. degree options: pure physics, applied physics and engineering (3-2 program), and engineering science (3-2 program). A 3-2 program is a five-year program where a student spends three years at Morehouse and two years at a partner engineering school. The Dual Degree Engineering Program (DDEP) is a 3-2 program offered with 13 partner institutions.[8]

The DDEP has been offered since 1969 and physics has been a part of it since the start. The applied physics degree portion started in the 2000s (a student receives a Morehouse applied physics degree and a B.S. in engineering from the partner engineering school). During 2012–2016, Morehouse awarded an average of eight bachelor's degrees per year to African Americans in physics.

Perspective of Department Chair, Faculty, & Staff

Recruitment & Retention

The physics department benefits tremendously from the rich history and legacy of Morehouse within the African American community. Faculty accomplishes retention under the "We C.A.R.E." ethos, with academic advisement being the strongest part of the acronym (Curriculum, Advisement, Recruitment/Retention/Research, and Extracurricular). This pedagogical approach combines sessions on culture, collaboration, and career alongside the Innovative Technology Experiences for Students and Teachers program (ITEST). ITEST includes research seminars, participation at national conferences, participation in summer internships and Research Experiences for Undergraduates (REUs), student competitions supported by various professional organizations and funding agencies, and incorporation of new teaching pedagogies and classroom technologies into the curriculum.

Faculty members participate in recruitment in various ways. Recruitment is achieved primarily via open-house events, current students and faculty visiting local schools, utilizing the alumni network, word-of-mouth advertisement, and the Nuclear, Materials, Space Sciences (NuMaSS) summer program for K–12 students. Admission to Morehouse is decided centrally and not by the department. The majority of the students who matriculate into the physics program are first-time college entrants from high school.

Retention is accomplished primarily through extremely active mentoring, with advisement being the main tenet driving the department's success in retention. Faculty meet with students two or three times per semester to make sure they are on track and understand any barriers that they currently or could potentially face. The

---

[7] In 2019, physics and the Dual Degree Engineering Program moved to the new Division of Mathematics and Computational Sciences at Morehouse. The college is organized into seven divisions, with Life Sciences being the other category in STEM.

[8] The partner engineering schools are Auburn University, Clarkson University, Dartmouth College (Thayer School of Engineering), Georgia Institute of Technology, Indiana University–Purdue University Indianapolis (IUPUI), Missouri University of Science and Technology, North Carolina Agricultural & Technical State University, Notre Dame University, Rensselaer Polytechnic Institute, Rochester Institute of Technology, University of Alabama–Huntsville, University of Michigan–Ann Arbor, and University of Southern California.

faculty must “touch” each student—that is, face-to-face meetings are preferred over email or on-line contact. The department provides tutoring led by top students and Saturday academies, led by a professor, that attract many students.

The key advice given by Morehouse faculty to other physics departments with regard to increasing their number of African American graduates is to have a critical mass of African American students—aim for at least five students in a cohort.

Curriculum

In “We C.A.R.E.” the C is for curriculum. The curriculum was developed so that when students graduate as physics majors, they will be prepared for graduate studies or a career. Physics majors are exposed to research through faculty in the department and through external collaborations. Some students do research at a nearby R1 research university. Local research physicists will sometimes engage Morehouse students in their research, which also helps faculty members to balance their workloads.

A senior seminar course (PHYS 450) is required, and it ensures that all students are introduced to research. Within this course, every student must present a research project before he or she can graduate. All of the students who attend the professional conference of the National Society of Black Physicists (NSBP) are required to give either a poster or oral presentation, which can be used to satisfy the senior seminar requirement.

Cocurricular Activities and Resources

The department has a strong and active chapter of the Society of Physics Students (SPS), and the former department chair served as national president of the Sigma Pi Sigma honor society. Physics majors have access to a common room during normal operating hours on campus.

Climate and Belonging

Students gain a sense of physics identity during their first year, and by their sophomore year, they identify as physics majors. The Morehouse first-year orientation is at the beginning of the semester, and there is also a big orientation for physics and engineering majors and their parents. The students get to see many other students who look like them and who can “do this.” This creates a special bond, which is part of the mystique for developing “the Morehouse man.” Faculty tell parents that they will take care of the students and will “raise them.” Faculty thus take on the role of surrogate parent and the students become part of a larger family or brotherhood. It was noted that adding new faculty who are kindred spirits with respect to student-centeredness is important in order to maintain a high level of commitment to student advising and mentoring.

Perspective of Administration (Office of the Dean and Office of the Provost)

Recruitment & Retention

The relatively small number of physics majors gives Morehouse an advantage. Morehouse has an “in your face” advising model called ADISA (Appreciative, Developmental, Intrusive Student Advising). *Adisa*, a Yoruba word meaning “She who is clear,” is very intensive regarding mentoring and advising, which goes beyond merely looking at which courses to take. There is a lot of contact, and advisers follow an intrusive advising model in order to keep students on track. It also involves calling, meeting, and talking to students to hear and understand their personal obstacles. Advising is part of faculty contracts, and faculty are asked to meet with students at least four times per semester. The model provides experiential learning opportunities for students and incentives for advisers that are connected to promotion and tenure. As an added incentive, faculty members get course release time when actively engaged in advising. Faculty members' training for ADISA is several days long during the summer, and a stipend is provided. Overall, Morehouse has four-year and six-year graduation rates of 48% and 56%, respectively.

Curriculum

The administrative line is as follows: president, provost, associate provost/dean of faculty, associate provost/dean of student success. There are no further deans of curricular units; there are, instead, divisional chairs who head up three divisions—Math and Science, Humanities and Social Science, and Business Administration and Economics. Department program reviews occur every three to four years to satisfy the Southern Association of Colleges and Schools regional institutional accreditation review. The DDEP is reviewed annually.

The overarching Morehouse mission is to develop men into leaders. Students are given opportunities to take on leadership roles in Crown Forum events, which bring speakers with socially conscious and global perspectives. According to Morehouse, the Crown Forum experience provides the means by which students may begin to meet the challenge of developing to their highest potential while forming a partnership with the academic program to foster a well-rounded college education. Each student is required to attend a minimum of six Crown Forum events per semester for six semesters. Additionally, there is a leadership center where students can engage in leadership training and courses. Community service is also mandatory. Every degree program has leadership baked into it, and there is a minor in leadership studies offered at Morehouse.

Cocurricular Activities and Resources

The upper administration provides each department resources including a budget, extra travel funds, and a special endowed fund to support departmental initiatives. Morehouse is the home of the regional Navy ROTC, and these students have to take physics courses. The Navy ROTC students do very well, and many transition into nuclear submarine positions.

Climate and Belonging

The new student orientation (NSO) is designed to grab the attention of students and their parents. It occurs over two weeks, and a closing ceremony, when the parents must leave their young scholars behind at Morehouse, seals the deal. The students and parents are marched to the campus gate, and the gate is closed after the parents are beyond it. This symbolizes the break between the parents and their adolescent sons and the beginning of Morehouse College custodianship for the next four years. At the NSO, students and parents learn about financial aid, the history of the college, the legacy, the Morehouse network, the young alums (wearemorehouse.com), and various campus policies.

All first-year students are housed in Graves Hall, and incoming classes have about 650 students each. Everyone at Morehouse appears to be dedicated to the students, and they communicate to the students that this dedication is to their success. From the beginning (i.e., at the NSO) there is an overwhelming feeling that everyone is pulling for the student to succeed. Morehouse is the place where black boys can go to become men. There, they can just be college students without having to deal with all of the issues that larger society presents to this particular demographic group.

Perspective of Students

Recruitment & Retention

Students are very supportive of one another, and the Morehouse brotherhood is strong. The option of the dual-degree program in engineering plays a significant role in the recruitment of students. Morehouse takes care of its STEM majors, and this is evinced by the growing number of them. Students are mandated to meet with their adviser at least once per semester. Unlike what was reported at most other institutions that the team visited, proximity to family was not given as a factor for college choice. Students feel that the professors are very supportive and that there is no other place quite like Morehouse. All students were recruited (in some aspect) to attend Morehouse and are receiving some type of scholarship from the institution.

Students perceive guidance from their advisers as great. Advisers view them and work with them as individuals to help them achieve their goals. The sense of closeness with faculty and being in small classes are big pluses for students.

Curriculum

Students feel that Morehouse has a nurturing environment with a challenging curriculum. Students are given the opportunity to study abroad in places such as Madrid. The option of the dual-degree program in engineering has played a significant role in the recruitment of students.

Cocurricular Activities and Resources

Students are encouraged to be whole people and to do things outside the department. Learning goes beyond the classroom, and the effort extended by the faculty is outstanding.

Climate and Belonging

The environment feels like a family atmosphere and is very engaging. Students feel extremely positive about the departmental climate. All of the students felt as though they had made the right choice to attend Morehouse and that the physics department shows them nothing but love. Students believe that Morehouse is good at building confidence and developing the collaborative spirit. They learn to thrive in any type of situation, and they are confident in their ability to learn.

University of Maryland College Park

Institutional and Departmental Profile

The University of Maryland–College Park (UMCP), a large public research institution located in College Park, Maryland, was founded in 1856. UMCP is the flagship land-grant institution for the state and has an enrollment of about 41,000 students. The Department of Physics has about 360 physics majors, with 24 being African American.

Each year about 7% of UMCP's physics bachelor's degrees go to African Americans (compared with a national average of 3.5% for the period 2014–2016). The salient features of the UMCP approach include special programs (some initially funded by NSF but sustained by UMCP); a climate in which many faculty and staff demonstrate awareness of diversity and inclusion; and centralized and multitiered advising, which gives students many opportunities to contact faculty, staff, and other support infrastructure. Academic features of note include a curriculum that introduces students to faculty research in a 100-level course (with faculty reflecting on their personal periods of struggle/challenge during the seminar), and PHYS 399, in which students explore concepts that explicitly help them develop their STEM identity. A supportive department culture and significant numbers of caring faculty and staff appear important for the retention and success of African American students.

Perspective of Department Chair, Faculty, & Staff

Recruitment & Retention

The UMCP physics department benefits because the institution has one of the most diverse populations of any large land-grant institution in the country. There is no formal pipeline from high schools. Physics and astronomy faculty participate in open-house events and other K–12 programs, thereby providing an opportunity for the department to reach high school students regionally.

Instead of focusing on programs for African American students, the school places its focus on ensuring that African American students are part of the community. Students receive formal mentoring (e.g., discussions of "What do you want to be?") in addition to academic advising. A required signature ensures that such a discussion occurs prior to registering each semester. It is at this stage that research opportunities are also mentioned to the students.

Curriculum

First-year students are offered a one-semester course (100-level, 1 credit) designed to inform them about research projects at UMCP. Faculty conduct weekly research presentations at which they share their personal stories and experiences along the road to becoming a scientist. Out of this, students get an understanding that persistence (rather than perfection) is a key indicator of success.

It is evident that faculty members care about their teaching as many of them have opted to adopt interactive components using clickers and providing real-time feedback on homework. Several faculty work in the subfield of physics education research (PER) to develop innovative pedagogical practices.

Cocurricular Activities and Resources

Involvement and leadership participation in the Society of Physics Students and other cocurricular activities are a function of individual student personality and science identity. All physics students have 24-hour access to a physics club room. The Office of Student Educational Services (OSES) and the Slawsky Clinic are special, professionally staffed offices that have been established within the Department of Physics as resources to help ensure students' success in and out of the classroom.

Climate and Belonging

Because of growth in the department (and in the numbers of underrepresented students), there are now four staff members who work together to advance equity, diversity, and inclusion in the undergraduate program.

The UMCP Physics Department culture includes a very active SPS, which hosts social activities and brings in speakers. Additionally, the department sponsors holiday parties and barbecues to bring students and faculty together outside the classroom.

Specific to the professional development of African American and other underrepresented students, there are two enrichment activities: African American students attend the National Society of Black Physicists (NSBP) meetings, and the Conference for Undergraduate Underrepresented Minorities in Physics (CU^2MiP) has been organized and hosted on the UMCP campus (in partnership with the National Institute of Standards and Technology).

Perspective of Administration (Office of the Provost, Office of the Dean, Office of Student Educational Services, and the Slawsky Clinic)

Recruitment & Retention

K–12 summer programs at UMCP attract a diverse population of participants, of whom 30–50% are African American.

One important factor for student success is to have a strong advising program. Faculty mentors are assigned to first- and second-year and transfer students. Individual advising is supplemented with group advising. During group advising, students are able to share with one another what faculty mentors have told them in order to gain a better understanding of the various ways to implement academic plans. This method also establishes a consistent baseline/platform for faculty advice and eliminates cases of conflicting input (e.g., one faculty member may advise a student to wait a year or two to do research, while another may suggest getting involved in research without delay; the group advising team is able to discuss the pros and cons of each approach to research). Peer mentoring is also considered an important aspect of student development. Peer mentors are trained in the dean's office, and from these peer mentors, students can receive help in developing their four-year academic plan.

Curriculum

Forming a support network begins with evaluating students along with their backgrounds (rather than evaluating only their student records). It is important to recognize talent and potential with background taken into account. The curriculum at UMCP allows students who are just starting physics to be successful. For example, there are a lot of courses that can be taken concurrently. Those who are accelerated can double major or take additional courses. Those who come in as transfers or are beginning with pre-calculus or pre-chemistry (rather than Calculus I or Chemistry I) are not hindered by prerequisites (and stacked courses).

For retention, PHYS 399, which emerged from an NSF S-STEM grant, provides community-building activities. Among other challenges, this course addresses imposter syndrome and provides mechanisms to minimize it. Likewise, the PHYS 170 seminar course offers identity-forming discussions for all first-year students. The

PHYS 170 course also provides weekly research presentations by faculty (along with the faculty member describing his/her own career pathway). Students are expected to write a reflection on each talk. These reflections enable the advisers to learn about each student for the purpose of guiding career paths.

Forty percent of all students at UMCP are transfer students. The curriculum is constructed such that students who transfer from community colleges know exactly how their courses map to the UMCP College Park courses. Including transfer students in REUs and summer bridge programs is also an important way to enhance the transition from the community college to UMCP.

Cocurricular Activities and Resources

Events allowing undergraduate students to engage with research are important. Each fall the Undergraduate Research Fair permits faculty members to set up and expose students to the breadth of research being done in the department. In spring, undergraduate students showcase their research in presentations.

There is a large living-learning culture composed of 1) tutoring in the dorms and 2) students in a single major living together in one dorm. The Physics Department has a large amount of nonprogram space for students to promote an inclusive culture.

Climate and Belonging

Undergraduate students in the Physics Department have a culture that is fully developed, and the students are self-organized. Ensuring that the lounge is a friendly space for underrepresented groups and women is a priority to ensure inclusion. Many African American physics students have support networks that extend outside the department (e.g., clubs, fraternities, and theme houses), and this is significant to their sense of belonging at the university. It also helps a great deal to have faculty and staff who can recognize, and can demonstrate awareness of, issues that can affect underrepresented groups, such as imposter syndrome and diminished self-efficacy. Mentorship, informally, can address these challenges, and having underrepresented faculty and staff members in the department can increase awareness as well.

Perspective of Students

Recruitment & Retention

Proximity to family was a general theme explaining the choice to attend UMCP. Students also said that the faculty demonstrate an awareness of high school disparities in STEM training and are willing to use office hours to mitigate these disparities. “Professors are open to explaining things thoroughly” was a general theme that we heard from the students. Openness of professors and their availability were reported as very important. Supportive and encouraging faculty created a positive experience for African American students.

Students remarked that it was important to have someone to discuss accomplishments with, someone who understands things at their level and who will push them. All students who met with the site visit team could identify a faculty or staff member whom they considered to be such a mentor.

Curriculum

Labs and lectures are independent courses at UMCP, and this is better, said students, because it permits them to separately highlight lab skills. The emphasis on skills such as working in teams, presenting in oral and written formats, and preparing to enter the professional workforce is also a benefit.

Cocurricular Activities and Resources

Students confirmed that faculty members are very open to having students engaged in research.

Climate and Belonging

Students generally reported being happy in the physics major at UMCP and said that time spent in the major has generally been a positive experience. The students shared several strategies (including support systems) for tackling challenges. An important factor is inclusion in study groups that are organically formed. The students termed these “friend groups” rather than “study groups” because the students do things outside of physics-related activities with their cohort. Other important factors are faculty awareness of how to work with students from various backgrounds, and finding African American faculty mentors even in other departments.

APPENDIX 7: SITE VISIT PROTOCOL

Before the Visit

The department chair and project directors (i.e., AIP staff) agree on terms of the visit. The chair returns signed contract to the project director who is coordinating the visit.

1. The project directors select a site visiting team (SVT) and coordinate dates with the department being visited. The SVT will consist of three people, one of whom may be a staff member of AIP. The project directors will inform the chair of the membership of the SVT, coordinate travel for the visitors, and assure that appropriate hotel and meal arrangements are made. The project directors will check with site visitors regarding special dietary and room arrangements. Two weeks before the visit, the project directors send each member of the SVT a packet of information about TEAM-UP, if needed.
2. The department prepares answers to a questionnaire given to the department chair along with the contract and sends it to the project directors at least two weeks before the scheduled visit. The project directors distribute copies of the questionnaire to members of the SVT. The department will also supply copies of catalog materials and, at its discretion, copies of recent external reviews or self-study evaluations.
3. A week before the visit, the department chair sends the site visit team chair a schedule of activities planned for the site visit, which will be shared with the project directors and the other site visit team members.
4. Two or three days before the visit, the SVT should meet via conference call or exchange email to identify issues and questions about the department.

It is essential that the site visiting team meet as a group before starting the visit. If possible, the team should plan to arrive in late afternoon and meet in the evening or have a breakfast meeting. The purpose of this meeting is to discuss the written material and prepare a strategy for finding answers to questions that arise. For the first meeting of the visit, the SVT will meet with the department chair.

During the visit (which is expected to last one day), the SVT should meet with: the chair, the coordinator of undergraduate programs, faculty in circumstances where informal discussion is possible, at least two groups of undergraduate students (both majors and non-majors), the dean or other appropriate administrator, key departmental staff, and others selected by the department. The number of formal presentations to the team should be kept to a minimum with all necessary factual information presented in the materials sent out before the visit.

At the end of the visit, the SVT should meet in executive session to discuss their report. If it seems appropriate, the SVT may meet with the chair to summarize their findings.

After the Visit

The chair of the site visit team appointed by the project directors is primarily responsible for drafting the team's report to the department chair and project directors. The initial draft should be circulated electronically to the SVT for comment and correction and then (within three weeks of the visit) sent to the department chair for correction of factual errors. The department chair will then have one week to respond with reports of errors or omissions. The report should be in final form and submitted electronically to the TEAM-UP project directors and the department chair not more than one month after the visit. The project directors will share the report with the members of TEAM-UP who are asked to keep it confidential.

Case studies to be included in the TEAM-UP report will be drawn from some of the site visit reports.

AIP TEAM-UP Site Visit Contract

The Task Force makes the following agreement with the Physics Department at _________________:

AIP will cover local expenses (housing, meals and local transportation during the visit) for the members of the site visit team. The department will cover any additional expenses.

AIP will work with the physics department to make appropriate hotel reservations for the site visit team. TEAM-UP will cover all travel expenses for the site visit team.

The department will provide the site visit team with written responses to a set of questions about the department's undergraduate program at least two weeks prior to the site visit.

In consultation with the site visit team leader, the department chair will set up a schedule of appointments with small groups of faculty (both in the department and outside the department as appropriate), students (both majors and non-majors and special groups such as engineers, pre-service teachers, etc.), clerical and technical staff, and administrators.

After the site visit, the site visit team will provide the department chair with a written report of the team's findings within three weeks of the site visit. The chair will have one week to correct factual errors in the draft and return it to the chair of the site visit team. The report in final form will be submitted to the department chair and AIP project directors. The report is written for the department chair. The chair may share the report with other members of the department and with the institution's administration at the discretion of the chair. The Task Force will seek the permission of the chair before using any of the data in the report in a way that links the data directly to the department. The Task Force may ask for additional data and comments as it prepares a Case Studies document.

Printed Name:

Signature

Date

APPENDIX 8: DEPARTMENTAL SELF-ASSESSMENT RUBRIC

The findings and recommendations of this report suggest a way for physics and astronomy departments to evaluate their effectiveness in educating African American students. This Appendix provides a self-assessment rubric modeled after one created by the New England Resource Center for Higher Education[9] and a similar one created by the AAS Task Force on Diversity and Inclusion in Graduate Education (Appendix X of Agüeros et al. 2019).

This rubric is organized into five areas corresponding to the themes of this report: Belonging, Physics Identity, Academic Support, Personal Support, Leadership and Structures. The rows correspond to the topics listed in Table 1 of the Change Management chapter, with a few changes to tailor the rubric to departments. The entries are meant to be typical of practices at each of three stages of progress toward the recommendations of this report. A department's actual practices will vary.

---

[9] Available at http://rengaconsulting.com/wp-content/uploads/2018/04/nerche_pi_rubric_self-assessment_2017.pdf

Belonging

	Stage 1: Emerging	Stage 2: Developing	Stage 3: Transforming
Faculty role	Most of the department's faculty focus on their research, though they take pride in their teaching. They feel that they treat all students equally.	Many of the faculty have taken a workshop on inclusion and belonging and they discuss student engagement in departmental meetings. The department holds several annual social events attended by students and faculty.	The department recruits faculty who are committed to supporting the success of every student in their program. All faculty welcome learning about the experiences of marginalized students and they recognize their own potential biases. Students say that faculty show in countless ways, large and small, that they care, including by skillfully rejecting stereotypes and ending microaggressions.
Student role	Students self-segregate by race, with only White and Asian students using the undergraduate common room. Comments such as "you're only here because of your race" are not challenged.	The department has created a code of conduct or values statement that stresses everyone is welcomed and valued in classrooms, student clubs, and common spaces. Minoritized students regularly hold leadership positions in SPS.	The department hosts discussion forums for students and faculty about belonging, stereotype threat, imposter phenomenon, and microaggressions. Minoritized students have their own club dedicated to recruiting and supporting new students. They also participate fully in SPS and common spaces.
Counterspaces	Black students are isolated in the department and university. They receive support from family members back home.	Black students participate in a campus-wide STEM or non-STEM association for Black scholars and they have a dedicated study space created by the office of student affairs.	The department creates a dedicated study space for students of color staffed by an expert in racial identity development. The department pays for a group of students, staff, and faculty to attend the annual NSBP conference. Faculty recognize the importance for students to find places where they can just be themselves.
Climate	The department is described as a praise-free zone where only the toughest are meant to survive. Students who suffer are told by peers that they should change majors.	The department chair periodically communicates norms and values of respect and inclusion. The department hosted a CSWP/COM Climate Site Visit but has not fully acted on the resulting recommendations.	The department consistently addresses concerns arising from a triennial climate assessment that factors in race/ethnicity/gender and other social identities. The strong sense of belonging of minoritized students has attracted the attention of peer departments, who want to learn how to be as successful.
Harassment response	Faculty are unsure what to do when an advisee describes experiencing sexual (or any other type of identity-based) harassment. The department chair calls Human Resources for help.	Faculty are knowledgeable about their reporting obligations under Title IX. They are familiar with their campus's bias response protocol.	Identity-based harassment claims are promptly reported to university authorities. The department has designated faculty, staff, postdoc, and student advocates who support a harassment-free environment.

Physics Identity

	Stage 1: Emerging	Stage 2: Developing	Stage 3: Transforming
Faculty role	When asked to describe the ideal physics student, most faculty reply, "someone like me." Most believe that success in physics requires only talent and hard work.	Most faculty understand the benefits of recognizing student success and giving encouragement. They send congratulatory notes to marginalized students for achievements and milestones.	The department tracks academic progress and analyzes differences by race, ethnicity, and gender. Faculty utilize evidence-based practices to strengthen students' sense of physics identity, including encouragement and recognition. The department funds student travel for physics-related career opportunities.
Student Role	Black students do not view themselves as part of the department, and often isolate themselves (e.g., they come to the department only to attend classes).	Black students come to departmental seminars and seek opportunities to participate in undergraduate research.	When asked to describe the ideal physics student, marginalized students respond that it could be someone like them.
Curriculum and Co-curriculum	Faculty encourage undergraduates to join their research group and select the "strongest" students.	The department has a Learning Assistant program and supports undergraduate attendance to identity based conferences (such as CU2MiP and the NSBP Conference).	The department utilizes physics education research methods, disaggregating by social identities, to assess whether their current activities foster physics identity. Working with students, faculty seek continuous improvement in their co-curricular support for physics identity development.
Faculty diversity	Faculty recruitment seeks the "best" hires based on letters of recommendation and who presents most strongly in their interview.	Faculty search committees are aware of implicit bias and utilize recommended search practices. They invite a diverse set of candidates to interview, but have not been able to retain faculty of color.	The department raised funds for an endowed chair designated to support equity and inclusion. Cluster hiring is utilized to recruit additional faculty of color, who join White faculty to mentor a growing number of underrepresented students.
Prosocial behaviors	Faculty are unaware of students' interests and activities related to outreach and community service. Academic success is what matters.	Faculty recognize and validate students' interests in outreach because it helps with recruitment. They invite successful alumni of color to speak to students.	Faculty communicate the ways in which a physics degree empowers graduates to improve society with particular benefit to marginalized groups. They volunteer alongside students in events that serve minoritized communities.
Career options	Career advising is left to a central campus office; faculty discuss graduate school options with students whom they think will succeed.	The department highlights the AIP/SPS Careers Toolbox during the departmental open house for recruitment and during a students' third year when advisers discuss career options with their advisees.	Every year the departmental colloquium series includes a physics alum working outside the profession. Faculty speak with equal pride about alumni working for non-profits, government, industry, and academia.

Academic Support

	Stage 1: Emerging	Stage 2: Developing	Stage 3: Transforming
Faculty preparation	Faculty have the opportunity to attend workshops at the campus center for teaching and learning.	All new faculty are encouraged to attend the New Faculty Workshop hosted by the AAPT in conjunction with the AAS and APS.	Department meetings feature discussions about pedagogy and curriculum. Senior and junior faculty participate in workshops on teaching and mentoring.
Faculty commitment	Most faculty are not engaged as mentors of undergraduate students. Faculty of color are not recognized for their informal mentoring of students of color.	The department has several exemplary mentors who regularly meet with majors.	The department tracks faculty time in both formal and informal mentoring and reduces other service obligations to compensate for these contributions. The department also funds a student-nominated prize for mentor of the year.
Advising	Faculty advisers meet with students once per term only to approve their class registration.	Faculty advisers complement professional advisers who support students' non-academic needs. The campus utilizes intrusive advising.	Faculty regularly check in with their advisees and get to know them personally. When concerns arise about academic, financial, or other issues, they contact the staff professional adviser.
Curriculum	There is one track for majors that begins with calculus-based mechanics and ends with a senior thesis as preparation for graduate school.	The major has several options for students interested in different careers. Students are also recruited into the department through popular general education classes.	The department regularly and quantitatively assesses recruitment activities and curricular pathways, identifying points at which students leave before graduation. With this information, faculty develop evidence-based, actionable plans to increase the persistence of all students to the degree.
Resource guide for students	The department website lists contact information for departmental staff, but no information on whom to turn to for help.	The department website includes a guide to the major, with detailed information on the support each office gives. The accessibility office reviews the website.	The department regularly asks students to review the departmental guide to the major for clarity, accuracy, and completeness. Every academic adviser discusses it with advisees.

Personal Support

	Stage 1: Emerging	Stage 2: Developing	Stage 3: Transforming
Financial	The department is generally unaware of students' financial needs. When questions arise they direct students to the financial aid office.	When departmental staff or faculty learn of a student's financial difficulties, they direct them to an emergency grant program.	Faculty are trained to recognize issues, circumstances and challenges affecting low-income students and to recognize opportunities to engage them with helpful information. Faculty know the relevant administrators in the financial aid and student services offices.
Paid work	Faculty grant proposals include requests for support of summer research students.	Faculty utilize campus resources to pay undergraduate research students during academic terms. They also advertise openings for student workers in the department.	The department has a paid Learning Assistants program and a portal advertising other paid positions for undergraduates. Faculty are aware of the limited time some students have on campus outside of classes due to work or other circumstances, and accommodate student needs accordingly.
Mental health	Mental health needs are not discussed in the department. All students are expected to be equally able, unless the student disabilities office informs the faculty otherwise.	Faculty show empathy to students who reveal they are under stress. They encourage students to seek help but are unsure where students can find it.	Faculty and staff normalize seeking help by discussing stress and self-care with students and referring them to campus resources. They provide extra time for assignments, emergency financial aid, and referral to counseling resources to students under financial, familial, or other forms of stress.
Intersectional identity	Faculty make an effort to treat all students the same. They appreciate diversity but do not understand why some students cannot leave their social identity outside the classroom and lab.	Faculty make an effort to learn individual students' backgrounds and interests outside the classroom. They recognize that students are different now than when the faculty member was a student.	Most faculty members understand and are comfortable discussing social identities, intersectionality, stereotypes, and marginalization. They recognize the unique promise of each student from a perspective of strengths rather than weaknesses. They join students in discussions of societal issues of concern to students.

Leadership and Structures

	Stage 1: Emerging	Stage 2: Developing	Stage 3: Transforming
Department chairs	Department chairs rotate every three years and serve to keep basic processes running, like assigning teaching and responding to problems. There is little scope for action.	The department chair strives to hear from students, staff, and faculty, and to leave the department in better shape than when they began. With learning from the APS New Department Chairs workshop and mentoring from the Dean, the chair is working to increase faculty diversity and set norms and values of inclusion and belonging. The department chair invites speakers from underrepresented groups.	The department has adopted a values statement and a code of conduct and has prepared a strategic plan for diversity and inclusion. The department chair convenes a monthly equity and inclusion luncheon open to everyone in the department and periodically hosts colloquia on the same topics. Given the department's success, the chair also advises other departments on how to enhance the success of African American students.
McNair and similar programs	The department does not engage with programs offered by student affairs or the multicultural center.	The department newsletter highlights the induction of McNair Scholars and showcases their academic success as part of its strategy to recruit additional African American majors.	The department partners with and financially supports campus programs for African American students, recognizing the importance of such programs for student belonging, professional identity development, and academic and personal support.
Campus resources	Physics faculty are aware of some campus resources to help students but do not know which ones are most helpful for specific needs.	Departmental administrators are well informed about campus resources including student affairs offices, dual-degree programs, research funding programs, multicultural centers, and tutoring centers. When students approach them with problems, they point students to help.	Faculty teaching large classes, undergraduate advisers, the SPS adviser and others regularly communicate with the administrators overseeing key support offices across campus. They are all part of a web of support for students.
Incentives and rewards	A lone champion on the faculty advocates consistently for, and provides personal support to, minoritized students. Ultimately, when this champion burns out, fails to get tenure, retires, or leaves the university, a void in support is felt by minoritized students.	Consistently with the stated departmental value of empowering students, the department chair provides funding and teaching releases to several faculty who mentor and support minoritized students.	The department norms and values hold every faculty member accountable for the success of all students. Faculty annual performance review, merit raises, and award nominations consider recruitment and mentoring of underrepresented students and other efforts advancing equity and inclusion.

6ab: Departmental Learning and Change	The department has little capacity to review national reports. Guidance for change comes internally from the Dean.	The department aspires to learn from reports of the physics and astronomy professional societies. Speakers are occasionally invited to present on these efforts but faculty generally see no reason to change.	Faculty are strongly committed to improving educational outcomes for underrepresented students. A Departmental Action Team includes faculty, staff, and students dedicated to assessing the culture and preparing a theory of change. The team has the support of the department chair and all members have attended a national workshop on leading change in physics departments.
6c: Faculty preparation and training	Some new faculty members attend the national physics and astronomy New Faculty Workshop. Their enthusiasm for innovation in education wanes when they learn that achieving tenure requires a single-minded focus on research.	The department encourages faculty of all ranks to propose new directions in education and diversity efforts, and supports faculty travel for professional development.	To support its newly formed equity and inclusion committee, the department has joined a national network organized by the professional societies. Coaches and facilitators work with committee members to help them create a culture of caring that can spread in the department.
6e: Ongoing data collection, assessment, and accountability	The departmental HR representative collects basic demographic data required by the institution for every enrolled student, postdoc, and employee: binary gender, race/ethnicity, and citizenship/visa status.	The department invites members to provide additional optional data on multiple social identities including gender identity, first generation college status, and anything else the member feels is important to their identity. The academic progress of majors through the curriculum is tracked and is used only by advisers for mentoring purposes.	The department performs annual self-audits on equity, inclusion, and accessibility as well as education, recruitment, and other processes, using self-assessment rubrics similar to this one. Policies and procedures are periodically reviewed for efficacy and equity across social identities and updated as needed. Every year the department prepares a summary of quantitative, qualitative, and descriptive data on diversity, equity, and inclusion for sharing with the Dean and visiting committees.

APPENDIX 9: RUBRIC FOR HIGH SCHOOL STUDENTS/PARENTS TO EVALUATE PHYSICS & ASTRONOMY DEPARTMENTS

Congratulations on your choice to enter one of the most rewarding, challenging, and fun careers! The TEAM-UP report was designed to examine the factors affecting the representation of African Americans in the field of Physics and Astronomy. This rubric was designed by organizing findings and recommendations into a score sheet. You can use this rubric, before making the decision to attend a particular school, to determine if the physics department will be supportive of your success. If you can, try to schedule a visit and an appointment with the department chairperson or the director of undergraduate studies to more fully ask questions framed by this document.

Belonging

Fostering a sense of belonging is essential for African American student persistence and success.

	Excellent	Good	Fair	Poor	Not Discussed
Faculty have strong & positive interactions with students (through research, projects, club activities, etc.).					
Student clubs and organizations are available, such as Society of Physics Students.					
Peers of the same affinity group are present in the department and/or university.					
Instances of microaggressions are acknowledged and addressed.					

Physics Identity

To persist, African American students must perceive themselves, and be perceived by others, as future physicists and astronomers.

	Excellent	Good	Fair	Poor	Not Discussed
Faculty have mechanisms to encourage and recognize student success.					
Students have the opportunity to attend and present at conferences.					
Students have the opportunity to perform research.					
Students have the opportunity to become Learning Assistants.					
Faculty and staff of the same race or affinity group are present to serve as role models.					
Students have the opportunity to participate in community service-based projects.					

Academic Support

Effective teaching and a strengths-based approach to academic support are necessary for African American student retention and success.

	Excellent	Good	Fair	Poor	Not Discussed
Faculty use state-of-the-art teaching methods in the classroom.					
Ways in which faculty demonstrate that students are valued by the department are discussed.					
Advising systems are in place which provide early warning of academic, financial and other difficulties.					
Resources are available for academic, financial and other difficulties (including mental health and stress).					
There are multiple pathways to degree completion (i.e. a variety of courses and each are offered each semester or at least once per year).					

Personal Support

Many African American students need support to offset financial burdens and stress.

	Excellent	Good	Fair	Poor	Not Discussed
Financial aid is available.					
Textbooks used are at reasonable cost or free.					
There are available mental health resources on campus.					
There are first-generation college graduates among the faculty.					
The university and department are able to report the number of first-generation physics and astronomy majors.					
The university and department acknowledge and welcome all aspects which relate to my affinity group.					
The department describes the various career pathways available to me with a physics or astronomy degree.					

Leadership and Structures

For sustainability, academic and disciplinary leaders must prioritize creating environments, policies, and structures that maximize African American student success.

	Excellent	Good	Fair	Poor	Not Discussed
Special programs exist to help students with physics identity and belonging.					
The department offers dual-degree programs and research funding.					
The university has a multi-cultural center.					
The university has a tutoring center.					
Students are made aware of the campus resources.					

APPENDIX 10: RESOURCES

General Information: Physics and Astronomy Inclusive Organizations and Other Resources

Committee on Minorities (COM): This committee of the American Physical Society addresses the production, retention, and career development of minority physicists and maintains data in support of these objectives. Committee members may suggest and conduct studies or facilitate programs that address this goal; the committee releases a report of their findings every year.

Website: https://www.aps.org/about/governance/committees/commin/index.cfm

Committee on the Status of Minorities in Astronomy (CSMA): As a committee of the American Astronomical Society, CSMA is dedicated to improving the engagement of underrepresented populations in the field of astronomy. This committee has created a roster, People of Color in Astronomy Listing, where AAS members can add to and access a list of people of color in this discipline.

Website: https://csma.aas.org/

Society of STEM Women of Color (SSWOC): This organization is focused on the promotion of women, specifically women of color, in STEM careers. Through community engagement, professional development, and scholarly research, SSWOC advocates for the increased support of women of color professionals in STEM.

Website: https://www.sswoc.org/

National Society of Black Physicists - Public Facebook Group: This public Facebook group is a space where individuals interested in the discussion about issues related to minorities in physics. This group includes nearly 350 members.

Website: https://www.facebook.com/NSBPInc/

African American Women in Physics (AAWIP) - Official AAWIP Facebook Page: This facebook group is a compilation of the African American women working in Physics, Astronomy and related fields. The page was created and is curated by physicist Jami Valentine Miller.

Website: https://www.facebook.com/aawip/

Black physicists and astronomers: The interviews: This article highlights the experiences and achievements of five Black physicists and astronomers.

Website: https://physicstoday.scitation.org/do/10.1063/PT.5.9036/full/

The HistoryMakers, The ScienceMakers Digital Archive: This national "non-profit research and educational institute [is] committed to preserving and making widely accessible the untold personal stories of both well-known and unsung African Americans." Their website provides access to the oral histories they have collected and archived, including the ScienceMakers Digital Archive. This archive includes 213 recounts from African American scientists from all STEM disciplines and is accessible after creating a (free) basic membership account.

Website: https://www.thehistorymakers.org/
Website for Becoming a Member: https://www.thehistorymakers.org/become-a-member
Website for The ScienceMakers Digital Archive: https://www.thehistorymakers.org/user/login?return=https://smdigital.thehistorymakers.org/home

The Untapped Genius That Could Change Science for Better: This TED talk by Jedidah Isler, the first black woman to receive a PhD in astrophysics from Yale, discusses her personal experiences of intersectionality as a black woman in higher education and physics.

Website: https://www.ted.com/talks/jedidah_isler_the_untapped_genius_that_could_change_science_for_the_better?language=en#t-413733

American Physical Society Strategic Plan: In 2019 the APS adopted a strategic plan in which equity, diversity, and inclusion are strongly interwoven.

Website: https://www.aps.org/about/strategicplan/index.cfm

Resources for Students

Access Network: Network of student organizations with a mission to create community amongst students in physics departments. Find out if your institution has a site or find info on how to start a site here: http://accessnetwork.org/

African American Women in Physics (AAWIP): Started by a Black woman who felt isolated in her own physics department, Jami Valentine created this website to honor African American women who have contributed to the physics community. As a resource, students can find inspiration to pursue a degree in physics and connect with other individuals interested in increasing diversity in STEM. This website serves as a platform to promote and archive the efforts that African American women have done to pave the way for other people of color to engage in physics or other STEM fields.

Website: http://aawip.com/

National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE): Established in 1972, this organization is dedicated to the professional advancement of people of color in STEM fields, especially those pursuing chemistry and chemical engineering. They engage with individuals and communities at all levels by developing scholarship, networking and career development opportunities for students and professionals of all ages.

Website: https://www.nobcche.org/

National Society of Black Physicists (NSBP): This organization has a long history of convening to celebrate African American and Black physicists dating back to the 1960s and was officially formed in 1977. It has since grown to become the most well-known and largest organization dedicated to the African American and Black Physicists community. This not-for-profit organization engages in the support and development of professional opportunities available to African American and Black students and professionals in the field of physics. Through supporting this underrepresented population, NBSP seeks to increasingly make visible the contributions of African Americans and Blacks in this discipline. The NSBP holds national conferences annually.

Website: https://www.nsbp.org/

National Society of Black Engineers (NSBE): Since 1971, NSBE has been dedicated to its mission of promoting Black and minority students in the field of engineering. NSBE functions on chapter, regional, and national levels. This organization develops a variety of different opportunities for students to be academically and professionally engaged in this discipline. Such opportunities include hosting outreach and networking programs, seminars and workshops, and an annual national convention.

Website: http://www.nsbe.org/home.aspx

TriCollege Libraries Research Guide, People of Color in STEM: This library guide complies a variety of resources focused on underrepresented populations in STEM fields. It highlights STEM organizations focused on underrepresented populations, scholarly articles and other literature related to people of color in STEM, and different media sources that discuss the disparities experienced by marginalized groups in STEM disciplines.

Website: https://guides.tricolib.brynmawr.edu/c.php?g=285559&p=1901688

United Negro College Fund (UNCF): Founded in 1944, this organization is invested in the academic future and success of students of color, especially students that identify as African American and Black. UNCF funds thousands of scholarships and thirty-seven HBCUs to provide direct and indirect support to underrepresented students during their higher education experience. As an advocate for college education and readiness, UNCF travels the country to engage communities in support of ensuring that minority students are able to pursue undergraduate and graduate degrees to compete in today's job market.

Website: https://uncf.org

Emerging Researchers National (ERN) Conference in STEM, Travel Awards: This conference is specifically held for students pursuing degrees/advanced degrees in programs funded by the National Science Foundation Human Resources Department Division and seeks to "enhance [students'] science communication skills and to better understand how to prepare for science careers in a global workforce." This conference also provides travel awards for students who apply and meet the outlined criteria.

Website: https://emerging-researchers.org/
Website for Travel Awards: https://emerging-researchers.org/travel-awards/

The Center of Excellence in STEM Education, Conference Opportunities: This website, through the University of Texas Rio Grande Valley, lists the most current conference opportunities available for higher education students in STEM.

Website: https://www.utrgv.edu/cstem/resources/student/conference-opportunities/index.htm

Careers Toolbox: This guide produced by the American Institute of Physics and the Society of Physics Students helps physics students and their mentors plan for successful careers in the workforce after completing a bachelor's degree.

Website: https://www.spsnational.org/sites/all/careerstoolbox/

Resources for Departments

American Physical Society Inclusion, Diversity, and Equity Alliance (APS-IDEA): A project funded by the APS Innovation Fund in 2019 dedicated to transforming the culture of physics departments to be more equitable and inclusive.

Website: https://www.aps.org/programs/innovation/fund/idea.cfm

American Physical Society Climate Site Visits: Since 1990, the APS Committee on the Status of Women in Physics and the Committee on Minorities have offered departments site visits to assess the departmental climate for inclusion of women and minorities.

Website: https://www.aps.org/programs/women/sitevisits/index.cfm

LGBT Climate in Physics Report: This report highlights the work conducted by the APS Ad-Hoc Committee on LGBT Issues that focused on the barriers to inclusion in the physics community for LGBT physicists. The report includes the committee's findings and recommendations to APS to promote inclusion for this population.

Website: https://www.aps.org/programs/lgbt/upload/LGBTClimateinPhysicsReport.pdf

American Astronomical Society, Task Force on Diversity and Inclusion in Graduate Astronomy Education: This report outlines and discusses recommendations made by the task force to astronomy departments in higher education, as well as the organization itself.

Website: https://aas.org/files/aas_diversity_and_inclusion_task_force_final_report.pdf

American Physical Society, Effective Practices for Recruiting and Retaining Women in Physics: This website includes various links that describe effective practices in recruiting and retaining women in physics from the undergraduate to career levels.

Website: https://www.aps.org/programs/women/reports/cswppractices/index.cfm

Effective Practices for Physics Programs (EP3): The American Physical Society and American Association of Physics Teachers are preparing a guide for self-assessment of undergraduate physics programs founded on documented best practices linked to measurable outcomes. The EP3 Guide will allow programs to create, improve, and assess their individual programs in a way that can respond to local constraints, resources, and opportunities, while being informed by current research and good practice within the discipline.

Website: https://www.aps.org/programs/education/ep3/

New Faculty Programs: The American Association of Physics Teachers, in conjunction with the American Physical Society and the American Astronomical Society, since 1996 has sponsored programs, including a Workshop and a Faculty Online Learning Community, to help new faculty at research and four-year and two-year institutions understand how to become more effective educators and support their quest to gain tenure.

Website: https://www.aapt.org/Conferences/newfaculty/

American Association for the Advancement of Science, SEA Change

SEA Change is a comprehensive initiative that implements a proven self-assessment process to effect sustainable change with regard to diversity, equity, and inclusion in STEMM at U.S. institutions of higher education. Institutions can now apply for a Bronze level certification.

Website: https://seachange.aaas.org/

The National Academies of Sciences, Engineering, and Medicine, Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine Report: This report explores the extent that women in science, engineering, and medicine field experience sexual harassment and how such experiences impact recruitment, retention, and advancement of women in these fields. This report also identifies and discusses preventative measures that have addressed sexual harassment in these fields.

Website: https://www.nap.edu/read/24994/chapter/1

The National Academies of Sciences, Engineering, and Medicine, The Science of Effective Mentorship in STEMM Report: This report seeks to support the talent development of all individuals in STEMM (STEM plus Medicine) through improved mentoring practices. The report presents findings and recommendations concerning the most successful mentoring practices as well as the most effective training for mentors and mentees.

Website: https://www.nap.edu/read/25568/chapter/1

Association of American Colleges and Universities, Project Kaleidoscope

Project Kaleidoscope is dedicated to empowering STEM faculty to support them in the effort to graduate more students in STEM fields.

Website: https://www.aacu.org/pkal

Inclusive Astronomy: The Nashville Recommendations: In June 2015, individuals from different sectors and disciplines gathered together to discuss the issues of diversity and inclusion in the field of astronomy. This posting summarizes their meeting and provides the group's recommendations for how to address and change the culture of astronomy to ensure that it becomes more inclusive of individuals of all identities.

Website: https://aas.org/posts/news/inclusive-astronomy-nashville-recommendations

Equity Scorecard and STEM Toolkit: The Center for Urban Education at USC has developed tools for colleges and universities to assess how institutional practices and resources, as well as individual actions and behaviors, affect equitable outcomes for all students.

Website for Equity Scorecard: https://cue.usc.edu/tools/the-equity-scorecard/

Website for STEM Toolkit: https://cue.usc.edu/tools/stem/

Equity in Mental Health: A framework of recommendations for colleges and universities to support the mental health of students of color jointly created by the Jed Foundation and Steve Fund. The framework academic institutions with a set of ten actionable recommendations and key implementation strategies to help strengthen their activities and programs to address the mental health disparities facing students of color.

Website: https://equityinmentalhealth.org/

Books and Articles for Faculty (see also the References section)

Chun, E. B., et al. (2015). *The Department Chair as Transformative Diversity Leader: Building Inclusive Learning Environments in Higher Education*. Sterling, VA: Stylus.

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., ... & Okpodu, C. M. (2016). Improving underrepresented minority student persistence in STEM. *CBE—Life Sciences Education*, 15(es5), 1–10. https://www.lifescied.org/doi/pdf/10.1187/cbe.16-01-0038

Grier-Reed, T. L., Madyun, N. H., & Buckley, C. G. (2008). Low Black Student Retention on a Predominantly White Campus: Two Faculty Respond with the African American Student Network. *Journal of College Student Development*, 49(5), 476–485. https://doi.org/10.1353/csd.0.0031

Jana, T., & Mejias, A. D. (2018). *Erasing Institutional Bias: How to Create Systemic Change for Organizational Inclusion*. San Francisco: Berrett-Koehler Publishers.

APPENDIX 11: RESEARCH LITERATURE SUMMARY

Introduction

In recent years, there has been a decline in the number of physics bachelor's degrees being earned by Black or African American students (Czujko, Ivie, & Stith, 2008).[10] The TEAM-UP task force's goal was to gather information about important factors that lead to the persistence of African American students in undergraduate physics and to use this information to make recommendations for best practices. While much of the research in the literature is focused on persistence, there is a growing body of literature that frames the experiences of African American students in the physical sciences and STEM more broadly.

However, there is still much to learn about the unique experiences of African American students in physics and astronomy.[11] Here we frame the task force study with a review of the relevant literature on African American student experiences in undergraduate physics. This research reflects and affirms many of the student experiences reported in our study. From this literature, we know broadly that physics culture creates environments that are not presently conducive to the success of students with marginalized identities, especially African American students. Optimistically, researchers have also identified departments, programs, practices, and organizations that are supporting these students to persist and succeed.

Research shows that aspects of STEM culture create barriers that African American students must learn to endure or overcome in order to persist in these fields. Traweek's seminal work *Beamtimes and Lifetimes* documented cultural markers for a particle physics community (Traweek, 1992). One feature that Traweek highlights is the "culture of no culture" ideology among physicists—the belief that in physics all things are objective and therefore cannot be biased (p. 162). Because of this "(non)cultural" framework, the field allows little room to advocate for the experiences of people who do not align with the characteristics and/or practices that are valued in physics. There is a lack of understanding among physicists that assigning "value" to characteristics and practices is, in itself, an act defining the culture. Research that examines the experiences of underrepresented groups in physics provides insight into how apparent this culture is and how it excludes, explicitly and implicitly, people from marginalized identities. Much of the work that looks at these experiences focuses on women in physics and tends to specifically highlight White women's experiences (Whitten et al. 2007). However, there is a growing body of research that investigates the experiences of African American students in STEM in general, and of women of color in physics in particular. It is from these bodies of work that we can frame the current understanding of the ways that physics culture impacts African American students.

---

[10] The terms *African American* and *Black* are often used interchangeably in this literature summary, though we recognize that the terms may hold different meanings for different authors, e.g., *Black* may signify only U.S.-born African Americans or may include broader groups of people of African descent. For reasons of fidelity, we use the preference of the authors we cite. To remain consistent with the rest of the report, we use *African American* when possible.

[11] Due to the dearth of research specifically on Black or African American students in undergraduate physics and astronomy, we include related work in this literature review. This encompasses online sources like news articles and blogs, as well as peer-reviewed articles on research about students of color broadly and African American students in physics-related and STEM fields.

Belonging

Sense of Belonging and Sense of Community

Students of color struggle to maintain a sense of belonging in physics-related fields. From studies on women of color, we know that these students report feelings of isolation that are linked to their ethnic background (Tate & Linn, 2005). Often, Black students have social circles outside of their STEM discipline and struggle to build social circles inside it. This manifests through difficulty finding study groups, issues with group work in classes, and feelings of invisibility and hypervisibility in classes (Kohli 2015).

How students perceive their racialized experiences in the physics field varies, depending on intersecting gender identities, economic status, and nationality. While African American students who succeed in physics cultivate strong academic identities, they still struggle to feel that they fully belong in physics and physics-related disciplines due to the effects caused by not being able to be their "whole self" while pursuing these fields (Fries-Britt, Johnson, & Burt, 2013). One way Black students have counteracted feelings of not belonging is through peer and faculty mentoring relationships. A study conducted by Shaun R. Harper shows that, especially at PWIs (Predominantly White Institutions), Black students turn to one another and to Black faculty for knowledge and strategies to persist (Harper 2013).

Studies show that HBCUs (Historically Black Colleges and Universities) and MSIs (Minority Serving Institutions) can serve as models for institutions looking to create communities of belonging for Black students (Arroyo & Gasman, 2014; Sciences, Engineering, & Medicine, 2019; Whitten et al., 2004). These institutions often have factors that contribute to student belonging, like diverse faculty who are able to be role models for students, programs that build community among students, and pipelines for student success at and beyond the institution (Arroyo & Gasman, 2014; Sabella et al., 2017; Sciences et al., 2019).

Imposter Syndrome and Stereotype Threat

Studies that examine the ways that science impacts one's sense of self often focus on the experiences of women and people of color. Through the investigation of constructs like belonging (Corneliussen 2015, Fries-Britt et al. 2013, Kohli 2015), self-efficacy and agency (Ko, Kachchaf, Hodari, & Ong, 2014; Ong, Ko, & Hodari, 2016), and identity (Hazari, Sadler, & Sonnert, 2013; Johnson, Brown, Carlone, & Cuevas, 2011; Ong, 2005; Ong et al., 2016; Tate & Linn, 2005), the broader STEM education community is pushing to understand the issues that continue to exclude women and people of color. African American students pursuing physics typically report experiencing imposter syndrome and stereotype threat at some point. Steele coined the term "stereotype threat" and defines it as a fear of reaffirming stereotypes associated with a demographic group that affects one's performance on certain tasks (Steele 1999). Ewing describes imposter syndrome as an "inner experience of intellectual phoniness" (Ewing, Richardson, James-Myers, & Russell, 1996). Both experiences can impact students from any background, but they can disproportionately affect African American students (Beasley & Fischer, 2012). The collective impact of these effects, in addition to struggles with a sense of belonging and other discrimination, contributes to the experiences that African American students have in physics and creates the exclusive environment that pushes these students out of the field.

Counterspaces

Counterspaces, or safe spaces, may work for African American students and other marginalized members to powerfully counteract feelings of not belonging, lack of community, and isolation, as well as experiences of stereotype threat in physics. Ong, Smith, & Ko (2018) identified five types of counterspaces for women of color in STEM: informal peer relationships; mentoring relationships, particularly with faculty or other senior members of the field; STEM diversity conferences, such as the annual meeting of the National Society of Black Physicists; STEM and non-STEM campus student groups, particularly those that include fellow students who share racial/ethnic or gender identities; and STEM departments that have strong policies and practices promoting inclusion.

Similar to counterspaces, the findings of Hyater-Adams (Hyater-Adams, Finkelstein, & Hinko, 2019) stress the importance of material resources (like STEM spaces with similar ethnic groups) and ideational resources (like departmental practices that promote inclusion) that encourage participation in the field for the identity of Black physicists. Fries-Britt et. al. (Fries-Britt et al., 2013) and Rosa & Mensah (Rosa & Mensah, 2016) both report that Black physics students' racialized experiences impact their sense of belonging in their departments. As described further below, relationships and interactions with faculty and peers have especially powerful effects on whether or not African American students have a strong sense of belonging and, in turn, choose to persist.

Physics Identity

Several studies suggest that science identity (and discipline-based STEM identity) are contributors and can be predictors of academic persistence (Brown, Mangram, Sun, Cross, & Raab, 2017; Hazari et al., 2013). This is echoed in physics education research literature, where developing an identity as a member of the physics field is seen as an important aspect of participation in the field (Wenger, 2010), and where it has been shown that having a "physics identity" correlates with the participation of marginalized students in the field (Hazari, Sonnert, Sadler, & Shanahan, 2010). The construct of physics identity was built from a framework for science identity that was applied to a sample of women of color who were students in STEM (Carlone & Johnson, 2007). Studies of identity at the intersection of physics, race, and gender provide insight into the struggles that students of color experience and strategies that they employ to continue in the discipline. Theory and empirical research that examine ways that students of color navigate their identities provide insights into the kinds of barriers that exist in the field, as well as the types of strategies that have been used to overcome them (Hyater-Adams et al., 2019; Hyater-Adams, Williams, Fracchiolla, Finkelstein, & Hinko, 2017; Johnson et al., 2011; Johnson, Ong, Ko, Smith, & Hodari, 2017; Rosa & Mensah, 2016).

Perceptions of Prejudice

There exist several studies on African American students in STEM, and reports that cite the need for more work and new measures for predicting the success of these students (Brown et al., 2017; Byars-Winston et al., 2016). Fries-Britt and colleagues conducted a series of studies with a group of Black undergraduate physics students in order to understand their racialized experiences in the discipline. One study reports that the majority of physics students in the study indicate that their race matters in their experiences studying physics and interacting with physics faculty (Fries-Britt, Younger, & Hall, 2010). However, the students differed from one another in their perceptions of how race impacted their experiences, as well as perceptions of their own responsibility for finding resources to cope with them. Examples of racialized experiences that students in this study described included pressures to represent their race and feelings of being judged differently because of their race.

A study with undergraduate African American women in physics reported common themes of experience for these students, including concerns about their academic preparation in the sciences, feeling supported by physics departments at HBCUs, coping with negative faculty interactions, and managing an academic and social life balance (Fries-Britt & Holmes, 2012). Many of these themes are echoed in other work on African

American students in STEM (Brown et al., 2017; Fries-Britt et al., 2013; Hyater-Adams et al., 2019; Rosa & Mensah, 2016). Another one of the Fries-Britt studies investigated the intersections of race, gender, academic ability, and class for African American students in physics. This study describes the desire that students had to be accepted for who they are and to have their multiple identities acknowledged and affirmed (Fries-Britt et al., 2013). A common theme of experience for students of color in academia in general and STEM specifically is the feeling of existing in two worlds and experiencing fragmented academic and social lives. This theme is used to stress the importance of intersectional studies that investigate how all of the identities African American students might have, in addition to their race, shape their experiences.

Physics/STEM Identities of Women of Color and Other Marginalized Students

Much of the research on identity in physics stems from work focused on the experiences of women of color broadly in STEM and in physics specifically (Blair, 2012; Ko et al., 2014; Ong, 2005; Tate & Linn, 2005). These studies use different frameworks of identity to understand the ways that women of color navigate their intersecting identities as they progress through their STEM careers. From these studies, we know that women of color often struggle to feel like "ordinary" members of the physics field. The low representation of women of color in physics contributes to these women's experiences of feeling both invisible and hypervisible when engaging in physics classes, labs, and conferences. Women report having to navigate discrimination from peers, faculty, and at times advisers who often doubt their abilities, as well as battle isolation in their departments with regard to important peer and faculty interactions. However, the women in these studies often employ agency and find methods to surmount the barriers in the field and cultivate their own unique identities as scientists (Johnson et al., 2011; Ko, Kachchaf, Ong, & Hodari, 2013). A key recommendation from this work for women of color looking to pursue STEM is to find and utilize strategies for taking up their multiple identities at once. Similar to the idea of wanting to feel "wholly oneself," as reported in work by Fries-Britt et al. (2013), these studies suggest women of color find counterspaces (e.g., communities, activities, and other spaces) where they can be valued for all of their identities—gender, racial, and scientific—without negative judgment (Fries-Britt et al., 2010; Ong et al., 2018).

Research on the ways that physics culture impacts women of color, specifically African American women, as well as nonbinary and trans students, finds similar and more nuanced themes of experience. Studies examining African American women's experiences in physics stress the complexities of intersecting forms of oppression. Rosa and Mensah report on the experiences of six Black women physicists and highlight the themes of these women being excluded from study groups, overcoming everyday racism and sexism, and availability or lack of funding as important factors in their decision to pursue, or not pursue, the field (Rosa & Mensah, 2016).

While themes of isolation and experiences of discrimination are common in this work, studies show that women and gender minorities encounter multiple forms of oppression (Atherton et al., 2016). APS released a report on the climate of physics for LGBTQ physicists, which found that students with additional marginalized identities (e.g., students of color) face greater discrimination than their White counterparts, and trans students experience the most hostile work environments (Atherton et al., 2016). Queer students of color reported hearing racist and homophobic comments from their colleagues as well as struggling to find spaces that support all of their intersecting identities. Trans students reported having concerns of safety in their departments and difficulties with policies on restroom usage and sex assignment on university paperwork.

Community Outreach

Previous research (Hazari et al., 2010; Ko et al., 2014; Ong, Wright, Espinosa, & Orfield, 2011) on students of color and their persistence within STEM has identified altruistic values as a motivator to pursue STEM majors and careers (Bentley, 2017). The ability to give back to one's community or society plays a significant role in decisions among students of color to pursue STEM and remain in their major. In a study conducted by Garibay (2015), findings indicated that "on average, Underrepresented Students of Color in STEM report that working for social change is more important to their career goals than their non-[underrepresented students of color] counterparts in STEM majors" (p. 15). Interviews with Black and Latinx engineering students in a study by McGee and Bentley (2017) emphasized how the culture of collectivism plays a role in these students' academic and personal lives; many shared how they wanted to take their STEM education and give back to their academic, home, and global communities. For example, one African American female participant shared how she mentors first-year students "to share lessons she had learned with mentees so that they would not 'make the same mistakes' " she did, but rather have the benefit of the "resources [she could] pass on to them" (p. 17). Similarly, Ko et al. (2014) reported that study participants—women of color in physics and astronomy disciplines—explained that they engaged in activism, such as encouraging minority girls in K–12 to explore areas of science and engineering, "as a way to help others after them pursue science, but sometimes as a way to help themselves in the process" (p. 187). Likewise, Ceglie (2011), Ceglie and Settlage (2016), Carlone and Johnson (2007), and Ong, Wright, Espinosa, and Orfield (2011) have all reported findings that depict how women of color pursue STEM disciplines to improve and give back to society in some way.

Academic Support

Faculty play a big role in the academic support of physics students in and outside the classroom. In the classroom setting, the pedagogies faculty use to teach can make an impact on student success. Much of the work from physics education researchers shows that effective pedagogies for teaching physics can change student learning outcomes (Finkelstein & Pollock, 2005; McDermott & Shaffer, 1992; Redish & Burciaga, 2004). Through interventions like flipped classrooms (Foote, Neumeyer, Henderson, Dancy, & Beichner, 2015; Robinson, Roland, Bosse, & Zayas, 2015), tutorials (Finkelstein & Pollock, 2005; McDermott & Shaffer, 1992; Redish & Burciaga, 2004), clickers (Keller et al., 2007; Perkins, Turpen, Sabella, Henderson, & Singh, 2009), and even lessons about equity and diversity (Daane, Decker, & Sawtelle, 2017), physics education researchers have shown that teaching physics with student needs in mind can make a difference in the competence and performance of students. However, while these classroom changes can be important, it is not guaranteed that changing teaching pedagogies will keep students, and specifically African American students, in physics classrooms and programs.

Research-based teaching strategies may not be enough when Black physics students still have negative interactions with faculty and perceive that the faculty in their department do not care about their academic success or their personal experiences (Bentley, 2017). There is evidence that students who feel that faculty who care about their learning are more interactive in the classroom (Blue, Wentzell, & Evins, 2015; Dancy, Rainey, Mickelson, Stearns, & Moller, 2016). In general, studies report that faculty who show they care about students can have a significant impact on the Black student experience in higher education (Fleming, Smith, Williams, & Bliss, 2013; Hurtado et al., 2011). In one study, Black students who perceived that their professors cared about their personal and academic problems were found to be more likely to interact with faculty in the department (Fleming et al., 2013; Hurtado et al., 2011). Another study showed that positive relationships with faculty and peers correlates with stronger engineering identity for Black and Hispanic undergraduate students (Hurtado et al., 2011).

Personal Support

Financial Concerns

Paying for college is a primary concern for many students and their families. Access to adequate financial aid resources can be either a hindrance or a facilitator for persistence, especially for African American students and students on STEM trajectories (Fenske, Porter, & DuBrock, 2000). Studies (Estrada et al., 2016; Perna et al., 2009; St. John, Paulsen, & Carter, 2005) show that African American students are strongly influenced by finances in terms of their college choice and decisions to persist, more so than their White counterparts. Adequate financial aid has been strongly correlated with persistence of URM students on STEM trajectories (Estrada et al., 2016; Fenske, Porter, & DuBrock, 2000; St. John, Paulsen, & Carter, 2005). In one report from the National Action Council for Minorities in Engineering, financial support is listed as a top-five factor related to minority persistence in engineering (Sciences, Engineering, & Medicine, 2011).

Unfortunately, financial aid for African American students wanting to pursue STEM undergraduate degrees is uneven across schools (Palmer, Maramba, & Dancy, 2011; Upton & Tanenbaum, 2014). Even for many African American STEM students who enroll in programs at HBCUs, paying for common expenses such as tuition, textbooks, and room and board can be experienced as extremely challenging (Upton & Tanenbaum, 2014). Perna and colleagues (Perna et al., 2009), who studied Black women undergraduates in STEM at Spelman College, found that to address their financial challenges, students often took on menial non-STEM jobs, which may have diminished the quality of their educational experiences. Perna et al. (2009) further noted that nontraditional students, such as those who commute, those who are financially independent from their parents, and transfer students, are especially vulnerable to financial struggles. Through financial aid, schools have the power to dramatically increase the number of African Americans graduating with degrees in physics, astronomy, and other STEM degrees. As Estrada and colleagues (2016) declared, “Institutions that are able to provide student financial support will produce stronger persistence and higher levels of student performance. This systemic element must not be overlooked in the universe of factors that impact the success of URM students in STEM” (p. 7).

Stressors and Mental Health

Dealing with stress is a common challenge that Black students in STEM face, and there is research focusing on the mental health of students of color. McGee’s work highlights the ways in which the stress caused by structural racism and sexism impact Black students pursuing degrees and careers in STEM fields (McGee & Bentley, 2017). McGee also argues that studies often focus on the resilience these students display in order to succeed in STEM fields, but often do not examine the social and emotional stressors (e.g., structural racism) that impact the well-being of these students (McGee, 2016). These experiences persist into the faculty level: African Americans are severely underrepresented among physics faculty (Pauls, 2014), and women of color make up only 1% of physics faculty nationwide. These faculty members are also likely doing extra mentoring work (Zambrana et al., 2015) and being paid less than their White counterparts (Li & Koedel, 2017). Recommendations about how to better support African American students in STEM include but are not limited to: department faculty and staff self-educating about the experiences of marginalized students, encouraging faculty to speak up in moments of microaggressions and bias, encouraging students to share their racialized experiences, creating a departmental family dynamic, and funding and developing programs and resources specifically to support students with marginalized identities (Ko, Kachchaf, Hodari, & Ong, 2014; Ong, 2005; Ong, Smith, & Ko, 2018; Sciences, Engineering, & Medicine, 2011; Whitten et al., 2004).

Academic Capital

In order to navigate the academy and the physics field, students require what we call "academic capital," which includes relationships, information, and resources to support understanding how the academic process works, as well as strategies to be successful. We can understand the types of capital that are necessary for the academic success of African American students by utilizing the categories of capital articulated in Yosso's work on community cultural wealth (Yosso, 2005). These categories of capital include: *social* networks of people and community resources; *navigational* skills for maneuvering within oppressive social institutions; *familial*, or cultural knowledge from family; *linguistic*, or intellectual and social skills attained through multilingual communication; *resistant* skills obtained from behavior that opposes inequity; and *aspirational*, or the ability to maintain one's hopes and dreams through barriers. Research shows that African American students in physics and STEM have different levels of access to these forms of capital compared with their White counterparts, and consequently experience specific barriers to participation (Rosa & Mensah, 2016; Yosso, 2005). In line with Yosso's capital categories, we see from research on the experiences of African American students in physics that family support, peer relationships, financial support, and availability of resources are critical forms of capital that contribute to the success of African American students (Bidwell, 2015; Ko, Kachchaf, Hodari, & Ong, 2014; Ko, Kachchaf, Ong, & Hodari, 2013). It is known that upon entering undergraduate institutions, African American men and women are often surprised that their high school education did not prepare them for the content in their introductory courses (Yosso, 2005). Structural discrimination such as red-lining (Tatum, 2003), the practice of controlling loans made to areas considered high risk because they are low-income (and often majority minority), makes it such that the K–12 educational experiences of students from various school districts can be dramatically different. Tatum (2003) also describes tracking, a phenomenon that occurs within racially mixed schools whereby students are divided into different level classes (i.e. remedial, college prep, honors, or AP), often along racial lines based on the recommendations of teachers who sometimes bring biases from their own past experiences. The result is that more students of color are placed in lower level classes, and those who do end up in AP classes often find themselves as the only one in their demographic in those classes.

Department Leadership and Structures

University physics departments are often the first place where students experience physics culture. Therefore, there are many studies that document the ways that departments do or do not provide access to the forms of capital that African American students need to succeed. Students report struggles with social relationships with peers in their physics departments, which creates barriers to things like study groups and day-to-day departmental information (Johnson, Ong, Ko, Smith, & Hodari, 2017; Ong, 2005). Strong, "intrusive," and sustained career advising (Rodgers, Blunt, & Trible, 2014), access to role models such as African American physicists (Arroyo & Gasman, 2014; Sciences, Engineering, & Medicine, 2019), opportunities to engage in hands-on research (Mitchell, 2014; Ong, Wright, Espinosa, & Orfield, 2011), and opportunities to engage in community outreach through their departments (Revelo Alonso, 2015; Trenor, Yu, Waight, Zerda, & Sha, 2008) have been shown to be effective means to retain African American students and other underrepresented students in physics, astronomy, and STEM.

Departments can positively impact the experiences of Black physics students by providing incentives for faculty care, incorporating already existing support programs (e.g., the APS Bridge program), and creating support mechanisms for the faculty (often faculty of color) who do the extra work to support Black students. A study on APS Bridge program students conducted by Chari & Potvin (2018) showed that the most significant factors in underrepresented students' choice of graduate programs are research options, funding, and faculty and peers of the same ethnicity. As discussed in earlier sections, faculty play a large role in the support of Black students inside and outside the classroom (Dancy, Rainey, Mickelson, Stearns, & Moller, 2016; Fleming, Smith, Williams, & Bliss, 2013; Hurtado et al., 2011). An example of how faculty of color go above and beyond to support Black undergraduate students can be seen in the creation of the African American Student Network (Grier-Reed, Madyun, & Buckley, 2008). Department leaders looking to better support Black students can find ways to incorporate efforts like these into their department structures.

References

Arroyo, A. T., & Gasman, M. (2014). An HBCU-Based Educational Approach for Black College Student Success: Toward a Framework with Implications for All Institutions. *American Journal of Education*, 121(1), 57–85. https://doi.org/10.1086/678112

Atherton, T. J., Barthelemy, R. S., Deconinck, W., Falk, Michael L., Garmon, S., Long, E., … Reeves, K. (2016). *LGBT Climate in Physics: Building an Inclusive Community* (p. 52). College Park, MD: American Physical Society.

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education*, 15(4), 427–448. https://doi.org/10.1007/s11218-012-9185-3

Bentley, L. C. (2017). Black college students' choice of STEM major: An analysis of their perceptions and experiences in their intended STEM pathways (Doctoral Dissertation, Vanderbilt University). Retrieved from https://etd.library.vanderbilt.edu/available/etd-09142017-153614/unrestricted/Bentley.pdf

Bidwell, A. (2015, May 7). African American Men: The Other STEM Minority. US News. Retrieved from https://www.usnews.com/news/stem-solutions/articles/2015/05/07/african-american-men-the-other-stem-minority

Blair, J. (2012, September 19). Where are all the black women in science? Retrieved October 30, 2019, from NewScientist website: https://www.newscientist.com/article/dn22258-where-are-all-the-black-women-in-science/

Blue, J. B., Wentzell, G. W., & Evins, M. J. (2015). What Do Students Want? Small Group Instructional Diagnoses of STEM Faculty. *2014 Physics Education Research Conference Proceedings*, 43–46. https://doi.org/10.1119/perc.2014.pr.007

Brown, B. A., Mangram, C., Sun, K., Cross, K., & Raab, E. (2017). Representing racial identity: Identity, Race, the construction of the African American STEM students. *Urban Education*, 52(2), 170–206.

Byars-Winston, A., Rogers, J., Branchaw, J., Pribbenow, C., Hanke, R., & Pfund, C. (2016). New Measures Assessing Predictors of Academic Persistence for Historically Underrepresented Racial/Ethnic Undergraduates in Science. *CBE Life Sciences Education*, 15(3). https://doi.org/10.1187/cbe.16-01-0030

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, 44(8), 1187–1218. https://doi.org/10.1002/tea.20237

Ceglie, R. J., & Settlage, J. (2016). College Student Persistence in Scientific Disciplines: Cultural and Social Capital as Contributing Factors. *International Journal of Science and Mathematics Education*, 14(1), 169–186. https://doi.org/10.1007/s10763-014-9592-3

Chari, D., & Potvin, G. (2018). Understanding the graduate school selection process from students' perspectives. *Physics Education Research Conference 2018*, 4. Washington, D.C. Retrieved from https://www.semanticscholar.org/paper/Understanding-the-graduate-school-selection-process-Chari-Potvin/c95ad129915614a8571f8abf7c3dfd3ceb335071

Claudio, L. (1997). Making more minority scientists. *Environmental Health Perspectives*, 105(2), 174.

Corneliussen, S. T. (2015, December 18). What unique perspective does a minority student bring to a physics class? *Physics Today*. Retrieved from https://physicstoday.scitation.org/do/10.1063/PT.5.8155/full/

Czujko, R., Ivie, R., & Stith, J. H. (2008). Untapped Talent: The African American Presence in Physics and the Geosciences. *AIP Report*. Number R-444. Statistical Research Center of the American Institute of Physics. Retrieved from http://eric.ed.gov/?id=ED503414

Daane, A. R., Decker, S. R., & Sawtelle, V. (2017). Teaching About Racial Equity in Introductory Physics Courses. *The Physics Teacher*, 55(6), 328–333. https://doi.org/10.1119/1.4999724

Dancy, M. H., Rainey, K., Mickelson, R., Stearns, E., & Moller, S. (2016). Influences of teaching style and perceived care of instructor on retention of underrepresented groups in STEM. *2016 Physics Education Research Conference Proceedings*, 92–95. https://doi.org/10.1119/perc.2016.pr.018

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., … Zavala, M. (2016). Improving underrepresented minority student persistence in STEM. *CBE—Life Sciences Education*, 15(3), es5. https://doi.org/10.1187/cbe.16-01-0038

Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. *Journal of Educational Psychology*, 103(1), 206–222. https://doi.org/10.1037/a0020743

Ewing, K. M., Richardson, T. Q., James-Myers, L., & Russell, R. K. (1996). The Relationship between Racial Identity Attitudes, Worldview, and African American Graduate Students' Experience of the Imposter Phenomenon. *Journal of Black Psychology*, 22(1), 53–66. https://doi.org/10.1177/00957984960221005

Fenske, R. H., Porter, J. D., & DuBrock, C. P. (2000). Tracking financial aid and persistence of women, minority, and needy students in science, engineering, and mathematics. *Research in Higher Education*, 41(1), 67–94. https://doi.org/10.1023/A:1007042413040

Finkelstein, N. D., & Pollock, S. J. (2005). Replicating and understanding successful innovations: Implementing tutorials in introductory physics. *Phys. Rev. ST Phys. Educ. Res.*, 1(1), 010101. https://doi.org/10.1103/PhysRevSTPER.1.010101

Fleming, L. N., Smith, K. C., Williams, D. G., & Bliss, L. B. (2013). *Engineering Identity of Black and Hispanic Undergraduates: The Impact of Minority Serving Institutions*. 23(1), 18.

Foote, K., Neumeyer, X., Henderson, C. R., Dancy, M. H., & Beichner, R. J. (2015). SCALE-UP Implementation and Intra-Institutional Dissemination: A Case Study of Two Institutions. *2014 Physics Education Research Conference Proceedings*, 83–86. https://doi.org/10.1119/perc.2014.pr.017

Fries-Britt, S., & Holmes, K. M. (2012). Prepared and Progressing: Black Women in Physics. In *Diversity in Higher Education: Vol. 12. Black Female Undergraduates on Campus: Successes and Challenges* (Vol. 12, pp. 199–218). https://doi.org/10.1108/S1479-3644(2012)0000012013

Fries-Britt, S., Johnson, J., & Burt, B. (2013). Black students in physics: The intersection of academic ability, race, gender, and class. In *Research on African American Education*. Living at the intersections: Social identities and Black collegians (pp. 21–39). Charlotte, NC, US: IAP Information Age Publishing.

Fries-Britt, S., Younger, T., & Hall, W. (2010). Underrepresented minorities in physics: How perceptions of race and campus climate affect student outcomes. In *Managing diversity:(Re) visioning equity on college campuses* (pp. 181–198).

Garibay, J. C. (2015). STEM students' social agency and views on working for social change: Are STEM disciplines developing socially and civically responsible students? *Journal of Research in Science Teaching*, 52(5), 610–632. https://doi.org/10.1002/tea.21203

Grier-Reed, T. L., Madyun, N. H., & Buckley, C. G. (2008). Low Black Student Retention on a Predominantly White Campus: Two Faculty Respond with the African American Student Network. *Journal of College Student Development*, 49(5), 476–485. https://doi.org/10.1353/csd.0.0031

Harper, S. R. (2013). Am I My Brother's Teacher? Black Undergraduates, Racial Socialization, and Peer Pedagogies in Predominantly White Postsecondary Contexts. *Review of Research in Education*, 37(1), 183–211. https://doi.org/10.3102/0091732X12471300

Hazari, Zahra, Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, n/a-n/a. https://doi.org/10.1002/tea.20363

Hazari, Zahra, Sadler, P. M., & Sonnert, G. (2013). The Science Identity of College Students: Exploring the Intersection of Gender, Race, and Ethnicity. *Journal of College Science Teaching*, 42(5), 82–91.

Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). "We do science here": Underrepresented students' interactions with faculty in different college contexts. *Journal of Social Issues*, 67(3), 553–579. https://doi.org/10.1111/j.1540-4560.2011.01714.x

Hyater-Adams, S., Fracchiolla, C., Finkelstein, N., & Hinko, K. (2018). Critical look at physics identity: An operationalized framework for examining race and physics identity. *+*, 14(1), 010132. https://doi.org/10.1103/PhysRevPhysEducRes.14.010132

Hyater-Adams, S., Fracchiolla, C., Williams, T., Finkelstein, N., & Hinko, K. (2019). Deconstructing Black physics identity: Linking individual and social constructs using the critical physics identity framework. *Physical Review Physics Education Research*, 15(2). https://doi.org/10.1103/PhysRevPhysEducRes.15.020115

Hyater-Adams, S., Williams, T., Fracchiolla, C., Finkelstein, N., & Hinko, K. (2017, July). *Intersectionality and Physics Identity: A Case Study of Black Women From Different Nationalities*. 4. Cincinnati, OH.

Johnson, A., Brown, J., Carlone, H., & Cuevas, A. K. (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching*, 48(4), 339–366. https://doi.org/10.1002/tea.20411

Johnson, A., Ong, M., Ko, L. T., Smith, J., & Hodari, A. (2017). Common Challenges Faced by Women of Color in Physics, and Actions Faculty Can Take to Minimize Those Challenges. *The Physics Teacher*, 55(6), 356–360. https://doi.org/10.1119/1.4999731

Keller, C., Finkelstein, N., Perkins, K., Pollock, S., Turpen, C., Dubson, M., … McCullough, L. (2007). Research-based Practices For Effective Clicker Use. *AIP Conference Proceedings*, 128–131. https://doi.org/10.1063/1.2820913

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). Retrieved from http://www.dl.begellhouse.com/journals/00551c876cc2f027,15acf57d20c58362,25f33efa41606057.html

Ko, L. T., Kachchaf, R. R., Ong, M., & Hodari, A. K. (2013). *Narratives of the double bind: Intersectionality in life stories of women of color in physics, astrophysics and astronomy*. 222–225. https://doi.org/10.1063/1.4789692

Kohli, S. (2015, June 21). *In 39 years, US physics doctorates went to 66 black women—And 22,000 white men*. Retrieved October 30, 2019, from Quartz website: https://qz.com/432756/in-39-years-us-physics-doctorates-went-to-66-black-women-and-22000-white-men/

Li, D., & Koedel, C. (2017). Representation and salary gaps by race-ethnicity and gender at selective public universities. *Educational Researcher*, 46(7), 343–354.

McDermott, L. C., & Shaffer, P. S. (1992). Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding. *American Journal of Physics*, 60(11), 994–1003. https://doi.org/10.1119/1.17003

McGee, E. O., & Bentley, L. (2017). The Troubled Success of Black Women in STEM. *Cognition and Instruction*, 35(4), 265–289. https://doi.org/10.1080/07370008.2017.1355211

Mitchell, V. M. (2014). *A phenomenological study factors African American female college students face participating in engineering STEM majors*. University of Phoenix.

National Academies of Sciences, Engineering, and Medicine. (2018). *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine*. https://doi.org/10.17226/24994

Ong, M. (2005). Body projects of young women of color in physics: Intersections of gender, race, and science. *Social Problems*, 52(4), 593–617.

Ong, M., Ko, L. T., & Hodari, A. (2016). Agency of women of color in STEM: Individual and institutional strategies for persistence and success. In *E. H. Branch (Ed.), Pathways, potholes, and the persistence of women in science* (pp. 183–195). Lanham, MD: Lexington Books.

Ong, M., Smith, J. M., & Ko, L. T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success: Counterspaces for Women of Color in Stem Education. *Journal of Research in Science Teaching*, 55(2), 206–245. https://doi.org/10.1002/tea.21417.

Ong, M., Wright, C., Espinosa, L., & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, 81(2), 172–209.

Palmer, R. T., Maramba, D. C., & Dancy, T. E. (2011). A Qualitative Investigation of Factors Promoting the Retention and Persistence of Students of Color in STEM. *The Journal of Negro Education*, 80(4), 491–504.

Pauls, S. (2014, July 14). *We Know Physics is Largely White and Male, But Exactly How White and Male is Still Striking* | Smart News | Smithsonian [News]. Retrieved October 30, 2019, from Smithsonian.com website: https://www.smithsonianmag.com/smart-news/we-know-physics-largely-white-and-male-exactly-how-white-and-male-still-striking-180952021/

Perkins, K. K., Turpen, C., Sabella, M., Henderson, C., & Singh, C. (2009). *Student Perspectives on Using Clickers in Upper-division Physics Courses*. 225–228. https://doi.org/10.1063/1.3266721

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., & Gary, S. (2009). The Contribution of HBCUS to the Preparation of African American Women for Stem Careers: A Case Study. *Research in Higher Education*, 50(1), 1–23.

Redish, E. F., & Burciaga, J. R. (2004). Teaching Physics with the Physics Suite. *American Journal of Physics*, 72(3), 414–414. https://doi.org/10.1119/1.1691552

Revelo Alonso, R. A. (2015). Engineering familia: The role of a professional organization in the development of engineering identities of Latina/o undergraduates. University of Illinois at Urbana-Champaign.

Robinson, S. P., Roland, G., Bosse, C., & Zayas, E. (2015). Effectiveness of flipped classroom techniques in an advanced laboratory physics course. *2015 Conference on Laboratory Instruction Beyond the First Year*, 92–95. https://doi.org/10.1119/bfy.2015.pr.023

Rodgers, K., Blunt, S., & Trible, L. (2014). A real PLUSS: An intrusive advising program for underprepared STEM students. *NACADA Journal*, 34(1), 35–42.

Rosa, K., & Mensah, F. M. (2016). Educational pathways of Black women physicists: Stories of experiencing and overcoming obstacles in life. *Physical Review Physics Education Research*, 12(2). https://doi.org/10.1103/PhysRevPhysEducRes.12.020113

Sabella, M. S., Mardis, K. L., Sanders, N., & Little, A. (2017). The Chi-Sci Scholars Program: Developing Community and Challenging Racially Inequitable Measures of Success at a Minority-Serving Institution on Chicago's Southside. *The Physics Teacher*, 55(6), 350–355. https://doi.org/10.1119/1.4999730

Sciences, National Academies of, Engineering, & Medicine. (2019). *Minority serving institutions: America's underutilized resource for strengthening the STEM workforce* (L. L. Espinosa, K. McGuire, & L. M. Jackson, Eds.). https://doi.org/10.17226/25257

Sciences, National Academy of, Engineering, N. A. of, & Medicine, I. of. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. https://doi.org/10.17226/12984

St. John, E. P., Paulsen, M. B., & Carter, D. F. (2005). Diversity, College Costs, and Postsecondary Opportunity: An Examination of the Financial Nexus between College Choice and Persistence for African Americans and Whites. *The Journal of Higher Education*, 76(5), 545–569. https://doi.org/10.1353/jhe.2005.0035

Steele, C. M. (1999). Thin ice:" Stereotype threat" and Black college students. *ATLANTIC-BOSTON-*, 284, 44–54.

Tate, E. D., & Linn, M. C. (2005). How Does Identity Shape the Experiences of Women of Color Engineering Students? *Journal of Science Education and Technology*, 14(5–6), 483–493. https://doi.org/10.1007/s10956-005-0223-1

Tatum, B. (2003). *Why Are All the Black Kids Sitting Together in the Cafeteria?: Revised Edition*. Basic Books.

Traweek, S. (1992). *Beamtimes and Lifetimes*. Harvard University Press.

Trenor, J. M., Yu, S. L., Waight, C. L., Zerda, K. S., & Sha, T.-L. (2008). The relations of ethnicity to female engineering students' educational experiences and college and career plans in an ethnically diverse learning environment. *Journal of Engineering Education*, 97(4), 449–465.

Upton, R., & Tanenbaum, C. (2014). *The role of Historically Black Colleges and Universities as pathway providers: Institutional pathways to the STEM PhD*. American Institutes for Research.

Wenger, E. (2010). Communities of practice and social learning systems: The career of a concept. In *Social Learning Systems and Communities of Practice* (pp. 179–198). Retrieved from http://link.springer.com/chapter/10.1007/978-1-84996-133-2_11

Whitten, B. L., Dorato, S. R., Duncombe, M. L., Allen, P. E., Blaha, C. A., Butler, H. Z., … Williams, B. A. (2007). What Works for Women in Undergraduate Physics and What We Can Learn from Women's Colleges. 13(1), 37–76.

Whitten, B. L., Foster, S. R., Duncombe, M. L., Allen, P. E., Heron, P., McCullough, L., … Zorn, H. M. (2004). " like a Family": What Works to Create Friendly and Respectful Student-Faculty Interactions. *Journal of Women and Minorities in Science and Engineering*, 10(3).

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, 8(1), 69–91.

Zambrana, R. E., Ray, R., Espino, M. M., Castro, C., Douthirt Cohen, B., & Eliason, J. (2015). "Don't Leave Us Behind": The Importance of Mentoring for Underrepresented Minority Faculty. *American Educational Research Journal*, 52(1), 40–72. https://doi.org/10.3102/0002831214563063

AIP

American Institute of Physics