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Leadership to Broaden Participation in Science, Technology, Engineering, and Mathematics *(Guest Editorial)*

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INTRODUCTION

Science, technology, engineering, and mathematics (STEM) fields are essential to a nation's economy, defense, global competitiveness, and the quality of life for its citizens. Given the importance of STEM in today's world, sustaining a nation's leadership in science and engineering requires the presence of a critical mass of scientists at the cutting edge of their fields. Scientists have the capacity to advance the frontiers of scientific knowledge, innovation, and application. The role of colleges and universities is central to supporting a nation's STEM enterprise. Colleges and universities are responsible for producing well-prepared generations of individuals to support and advance every major STEM field. This special issue of *The Journal of Negro Education* explores a range of strategies advanced by many of our nation's historically Black colleges and universities (HBCUs) to lead efforts to produce STEM graduates of color, especially African Americans. Their efforts are particularly important in view of the nation's changing demographics which reflect enormous increases in racial and ethnic diversity.

STEM fields will drive much of the United States' domestic and global economies for the foreseeable future. According to Zilberman and Ice (2021), employment projections from the U.S. Bureau of Labor Statistics (BLS) 2019-29 show that occupations in the STEM fields are expected to grow 8 percent by 2029, compared with 3.7 percent in all other fields. Advances in STEM will improve the quality of life for humankind, provide solutions for saving the planet, and enable a better understanding of the human experience singularly and collectively. Along with these advances will come new and exciting career opportunities for future generations.

Although these opportunities will exist, recruiting and retraining skilled STEM workers proves to be difficult. In the 2014 report, *Still Searching: Job Vacancies and STEM Skills,* The Brookings Institution reported, "the median duration of advertising for a STEM vacancy is more than twice as long as for a non-STEM vacancy (Rothwell, 2014)." Moreover, a 2007 joint report from the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine warned the United States of a *gathering storm*—the decline of a critical mass of individuals in the domestic workforce capable of continuing to drive the nation's STEM leadership in innovation and productivity. This same report also cited data signaling that the United States' advantages in the science and technology marketplace were beginning to erode.

Some of the decline cited in these reports and others is related to the nation's over-reliance over the years on international talent for its science and engineering (S&E) fields. This STEM recruitment and retention strategy is not sustainable for three key reasons. First, talented STEM professionals from other countries are finding opportunities in their home countries, making it increasingly attractive for them to remain there, after graduation. Second, new players for global STEM dominance are entering the competition for both global leadership and the attraction of a strong STEM workforce, e.g., several countries in the European Union, Canada, and Australia. Countries such as India and China are now building their own strength and global competitiveness in STEM. For instance, the National Science Board noted in its 2020 publication, *Science and Engineering Indicators 2020: State of US Science and Engineering*, the U.S. awarded close to 800,000 "first-university" degrees (broadly equivalent to a bachelor's degree) in S&E fields in 2016 while China awarded 1.7 million, a number that has doubled over the last ten years. Within the

same report, the National Science Board mentioned that the United States has fallen to #3 globally, behind countries of the European Union and China, in the annual number of scientific publications while China's numbers have increased tenfold since 2000 (NSB, NSF, 2020). Finally, a rising national surge of xenophobia and racism against non-Whites in the United States make the country less welcoming and less hospitable to scientists of color who now have an increasing number of global options to consider.

These are real threats to the standing of the United States as a world leader in STEM, the emergence of which did not happen overnight or haphazardly. The United States led the world throughout the Industrial Revolution, the Atomic and the Space ages, and it remains at the forefront of scientific and technological advances. To maintain its global dominance in S&E, the United States must build a diverse home-grown STEM workforce.

Illustrative of the nation's challenges to diversify its STEM workforce is the continuing underrepresentation of Black and other scientists and engineers of color at the doctoral level. In comparison to their proportions in the overall U.S. population, data collected by NSF show Whites and Asians overrepresented in S&E doctoral degree production (NCSES, 2020). With respect to African Americans—approximately 13% of the U.S. population—the productivity of STEM doctorates over approximately three decades has only risen from about 2.5% to slightly more than 5.5% today (NSF, 1995; NCSES, 2020). While White women have recently made significant advances in STEM doctoral productivity, especially in the biological and life sciences, African American women have not made comparable gains and lag disproportionately behind the advances of White women in all STEM fields.

Two large segments of the United States population are underrepresented in STEM—women, who comprise more than half of Americans (a majority of college and university students) and people of color, who comprise more than 40% of the national population. Numerous reports document that White males continue to dominate STEM fields of study, even though they constitute slightly more than 40% of the total enrollment in U.S. colleges and universities. The underrepresentation of women and people of color in STEM, especially at the undergraduate level, signals continued underrepresentation in STEM doctoral degree attainment and ultimately STEM faculty appointments. Increasing racial and ethnic diversity in STEM must be considered a national imperative, especially because the U.S. Census Bureau projects that people of color will become a majority of the nation's population by 2044 (Colby & Ortman, 2014).

Recognizing this imbalance and an underutilized pool of talent, the National Science Foundation (NSF), under the direction of the congressionally mandated Committee on Equal Opportunities in Science and Engineering (CEOSE) has prioritized the achievement of greater representation of women and underrepresented groups of color in its focus and funding. According to the NSF website, CEOSE now serves as a critical advisory committee to the agency on policies and programs that encourage full participation by women, minorities, and persons with disabilities in STEM (NSF website: https://www.nsf.gov/od/oia/activities/ceose/). The NSF has termed its efforts to increase full participation of these groups in the STEM fields as *broadening participation*. This term has gained much traction and is used extensively in the STEM fields and most notably within NSF solicitations, proposals, and programs. The concept of broadening participation aligns with NSF's stated goals: "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense."

Much of the work of diversifying the STEM workforce is carried out by minority-serving institutions (MSIs) which include HBCUs. Despite their overall large enrollments, top tier liberal arts colleges and flagship universities have often not been wellsprings for potential African American STEM doctoral students (Taylor & Wynn, 2019). However, the nation's HBCUs produce a disproportionately large number of African American undergraduate students, given their overall enrollment numbers, who later earn S&E doctoral degrees (Clavier et al., 2021). Examination of the most recent statistics on the baccalaureate origins of African Americans who later earn STEM doctorates makes the case for HBCUs as a national reservoir of African Americans for graduate matriculation in STEM. Six of the top ten such institutions are HBCUs—some even with relatively small undergraduate enrollments. For example, Spelman College, with only 2,000 African

American students (almost all African American women) ranks number two (number one on a per capita basis) of *all* institutions in the country that produce African American undergraduates who later earn S&E doctorates (NCSES, 2021). Many predominantly White institutions (PWIs) have considerably larger African American undergraduate enrollments than Spelman and other HBCUs, but their records in producing African Americans who later earn doctorates in STEM are typically lower. Furthermore, while only 9 % of African American students currently matriculate at HBCUs (and graduate approximately 13%), in some STEM fields HBCUs graduate an even higher percentage of African Americans, e.g., in the physical sciences and mathematics (U.S. Department of Education, 2021; Upton & Tanenbaum, 2014).

The NSF's Historically Black colleges and Universities Undergraduate Program (HBCU-UP) seeks "to assist HBCUs in their effort to strengthen STEM education and research capacity as a means to broaden participation in the Nation's STEM workforce" (HBCU-UP website: https://hbcu-up.org/). Considering the enormous effort by HBCUs, federal grant programs serving these institutions should be expanded and infused with larger sums of money. Furthermore, HBCUs should be prioritized as a potential source for highly talented—and motivated—African American students for doctoral study.

Mere enrollment of African American students in undergraduate STEM programs is insufficient, however, for broadening participation. Even more meaningful is the institutions' capacity to graduate students from STEM programs and advance many onward to STEM doctoral degree attainment. The success of HBCUs in broadening participation in STEM is not the result of substantial funding, world class facilities or a preponderance of nationally and internationally decorated faculty (i.e., Nobel Laureates, Fellows of the National Academies, etc.). Rather, *leadership* and *commitment* of faculty, administrators, and others on HBCU campuses may be major contributors to their success in STEM student productivity.

There is ample evidence to demonstrate the important role of HBCUs in educating and graduating Black STEM professionals. To accomplish this goal, leadership at all levels of these institutions has intentionally focused on building and sustaining a culture of support for STEM students, as well as a range of leadership strategies for ensuring institution-wide alignment. These leadership attributes and institutional characteristics seem to be inextricably intertwined in supporting STEM success.

THE GENESIS OF THIS SPECIAL ISSUE OF *THE JOURNAL OF NEGRO EDUCATION*

The idea for this special issue of *The Journal of Negro Education (JNE)* grew out of the work of the Center for the Advancement of STEM Leadership (CASL). Established with generous funding from the NSF in 2016, CASL is a collaborative research, education, and knowledge transfer/outreach entity. The partnering institutions are the University of the Virgin Islands (UVI), North Carolina Agricultural & Technical State University (NC A&T), Fielding Graduate University, and the Association of American Colleges and Universities (AAC&U).

HBCUs' remarkable track record in educating and graduating African American students in STEM documents their significant contributions to broadening participation in STEM fields. Thus, CASL seeks to position HBCUs as the leading voice in the national discourse on broadening participation in STEM higher education (Mack et al., 2019). As top producers of African Americans who graduate in STEM—and many who later earn STEM doctorates, CASL posits that *leadership* attributes (emanating strongly from African American cultural legacies) of individuals at *all* institutional levels foster an environment of support and success for STEM students (CASL website: http://advancingstemleadership.net).

Overview of the Special Edition

A total of twelve articles are presented in this special issue of JNE—seven by CASL researchers and five complementary articles by non-CASL authors. Except for one article that focuses on K–12 STEM education, the articles reflect leadership styles and strategies used by leaders at various s

levels of the HBCU enterprise—administrators, faculty, staff, and others—to advance STEM education and research. Participants in the studies are experienced, competent, and bold; and their leadership behaviors are largely in alignment with the legacies, missions, and values of their institutions, grounded in their personal cultural contexts. These qualities result in institutions where, according to Jaeger and co-authors, leadership and structure intersect to support STEM student success through a STEM-oriented mission and vision. While not all the attributes associated with this intersection are present in every institution, each institution in this study demonstrated one or more of the leadership-structure intersectional relationships.

The research and theoretical frameworks presented in this special issue of JNE reflect three dimensions of effective HBCU leadership for advancing STEM diversity in the HBCU context: (a) culturally oriented, values-driven leadership; (b) leadership at multiple institutional levels; and (c) systemic and collaborative leadership orientations. These three dimensions are synergistic in that they collectively represent the types of structures and processes that are essential to HBCU success in graduating significant numbers of African American STEM students—and sending a significant number onward from the undergraduate level to successfully pursue doctoral degrees in STEM at universities of all types, nationally and globally.

Culturally Oriented, Values-Driven Leadership

The articles in this dimension of HBCU leadership suggest that the cultivation of values-driven leadership at multiple levels, like at many other types of institutions, requires leadership development activities that are congruent with the values of the institutions, and which engage the spiritual dimensions of leadership, as well as the cognitive, affective, and behavioral domains. Recognizing the complexity of leadership at HBCUs with a focus on advancing STEM, McClintock and co-authors identify the elements and impact of the leadership development program launched by the previously mentioned NSF-funded Center for the Advancement of STEM Leadership that incorporates several aspects of leadership and learning modalities.

Boncana and associates document some of the assets that are bedrock within the fundamental HBCU culture which are essential for creating and leading an environment of success for African American students in STEM. They highlight the HBCU historical commitment to nurturing students' intellectual growth and development, as well as the enhancement of their self-efficacy, cultural and professional connections, especially in STEM fields, and overall well-being. This commitment also includes a recognition of the nature and needs of the HBCU student population which is reflected in the leadership behaviors at these institutions.

Specifically, McGee and coauthors point to policies and practices which acknowledge the race-conscious mission of HBCUs and the role of college presidents in creating an educational environment that allows Black STEM students to thrive. The leadership demonstrated by the study participants integrates Gallos and Bolman's (2021) four frames of academic leadership: structural, political, human resource, and symbolic. The authors argue that race-conscious leadership in education can effectively help dismantle the effects of systemic racism. In this study, especially, the authors emphasize the importance of the presidents' awareness of and skill in navigating the political climate in which they, their institutions and their communities are situated. Such political effectiveness not only opens pathways to successfully resourcing their institutions through external funding, but it enables college presidents to form strategic partnerships with other minority serving institutions and PWIs to access greater educational resources and experiences for STEM students. Consistent with race-conscious leadership, the presidents in McGee and coauthors' study prioritize recruiting and hiring Black faculty and ensuring the presence of resources and structures to support the success of faculty. These faculty, in turn, mentor and serve as role models for students.

Culturally sensitive leadership is attentive to the needs of specific populations within the HBCU community, and it supports programs and activities to meet those needs. As Morton notes, for example, Black Women in STEM encounter particular challenges. She documents programs and activities which foster peer communities, such as the "Sistah Groups," which are essential elements of a comprehensive supportive environment. Such programs that support African American STEM

students can be informed by critical race theory (based on contextual U.S. history of race relations), as well as an ethic of care which aligns with, and adds, another dimension to Hendrickson's framework. Additionally, in Morton's context, students become leaders by engaging in peer support activities.

Leadership at Multiple Levels—Intentional Leadership Development

While presidents and provosts have significant roles in funding and policymaking, institutions that are fully committed to STEM success require both positional and non-positional leaders. Like Hendrickson, Blackmon and others note in their article, responsibility for a humanistic-educative caring ethos, which is an important dimension of advancing student success in STEM at HBCUs, rests with all levels of leadership.

These authors posit that the interplay between leadership characteristics and institutional factors underscores the importance of vision and boldness. They note, for instance, that presidents take the lead in creating and maintaining an institutional environment supportive of STEM diversity. Thus, the presidential role requires incumbents to have the ability to fill five roles: as strategists, communicators, motivators, politicians, and legitimators. They conclude further that presidents must interface with external as well as internal stakeholders at multiple levels; and articulate not only the mission and vision of the institution, but translate these attributes into policies, resources, and a cohesive and aligned community that advances STEM and other disciplines. In addition, they must have vision, competence, experience, and skill in navigating complex and sometimes competing demands of stakeholders.

Blackmon, Hendrickson, and others also document the leadership role of provosts at successful STEM-oriented HBCUs. These leaders are found to have a clear commitment to nurturing both faculty and students, building collaborative teams and employing a leadership style that has both "breadth and depth," emphasizing relational and systemic qualities. Like the president, the provost inspires, motivates, and maintains the collective energy toward the shared institutional goals of increasing STEM student productivity. Provosts, especially those who have come through the faculty ranks, are likely to understand the needs of faculty and address those needs through various policy and budgetary initiatives. Similarly, leaders whose own educational backgrounds or experiences in a STEM discipline may be particularly helpful in seeking grants or serving as principal investigators on extramurally funded projects that support STEM research or student support.

While Hendrickson's study examines a culture of caring at the level of middle academic managers (e.g., academic deans), the thoughts and processes of leadership models at this level are typically congruent with the perspectives of presidents and provosts in the study by McGee and coauthors. A humanistic-educating caring institutional culture depends upon fidelity to *both* knowledge and persons and must be embodied in all aspects of the institution. Fidelity to knowledge perceives STEM knowledge as transdisciplinary, cross-disciplinary, and multi-disciplinary, with a focus on modes of reasoning and meaning making. Fidelity to persons is consistent with attention to the well-being and achievement of learners. Hendrickson posits that academic caring exists as an aspect of HBCU culture. In his framing of non-positional leadership, individuals at any level can serve as champions for STEM education. Academic caring by middle academic managers is demonstrated in quality of relationships and interpersonal interactions, as well as values-informed decision making to generate resources and to remove barriers to success. Caring leaders reportedly have the skill to communicate effectively, transparently, and inclusively and to intentionally build a community of STEM champions. In a caring model, STEM faculty take responsibility for ensuring student success. This skill means creating a learning environment that reflects fidelity to knowledge and fidelity to persons.

While several articles in this special issue emphasize the importance of leadership experience for presidents and provosts, emerging STEM leaders can benefit from leadership development through programs which include professional coaching. While structured leadership development models can provide a theoretical framework for STEM leadership, theory-based professional

coaching can prepare STEM leaders to work more confidently with the complexities of leading at HBCUs. The pilot program documented by Okpala and colleagues complemented other elements of CASL's Leadership Development Program by supporting participants in conducting leadership projects on their campuses. The positional levels of program participants reflect the multi-level leadership evidenced in other studies presented in this special issue. In addition to modeling and motivating effective STEM leadership, coaches supported emerging leaders in engaging perspective-taking and broadened resource generation. Consistent with Jaeger's five institutional structures, coaching developed leadership skills aligned with STEM commitment, a STEM inspirational environment, and resource generation.

As several studies in this special issue show, fostering diversity in STEM requires intentional leadership at every level of the educational system, including K–12. The study by Sampson and Clayton places a spotlight on the specific needs of African American female students. Applying the lens of critical race theory, the authors demonstrate the essential role played by transformative school principals in promoting the success of female students. Such success, particularly in K–12 STEM classes, is essential for establishing the foundation for subsequent and successful STEM matriculation at the college level.

Collaborative Leadership to Build Resources

The unique success of HBCUs in broadening STEM participation invites consideration of institutional and leadership characteristics which might inform that success. Using data from multiple sources, Jaeger and coauthors identify those leadership attribute factors which appear to be predictive of institutional success. Similarly, Huang and others seek to develop a deeper understanding of the psychosocial and structural factors influencing STEM student experiences at six geographically diverse HBCUs.

Effective racially and culturally attuned leadership is shown to be essential in fostering institutional cultures and programs supportive of student success in STEM. Two studies in this volume (Jaeger et al. and Huang et al.) use case study and mixed methods respectively to identify factors which contribute to STEM student success at HBCUs. Several of the findings in these articles are echoed in the literature reviewed by Toldson and his colleagues. Recognizing the need for a valid and reliable instrument to measure the relationship between the identified factors and student success, Toldson and coauthors designed and tested an instrument to "spur more rigorous research on the academic, social, and cultural factors associated with HBCUs' success in recruiting, retaining, and graduating Black STEM students." The study systematically evaluated twenty-five institutional variables and identified seven factor groups for a survey of student perceptions of their experiences. The survey was tested with 2,900 student respondents and statistical tests applied to determine internal and predictive validity and reliability. Overall, the survey instrument was shown to be a valid and reliable means to measure STEM student experiences at HBCUs.

According to Huang and coauthors, leader and institutional commitment to student success includes ensuring resources and structures to support student learning, mentoring, and opportunities for STEM workplace experiences. Such activities advance the capacity of HBCU STEM graduates to be competitive in the global arena and to prepare them for STEM Ph.D. programs. Students at HBCUs with successful STEM programs are provided the tools and knowledge they need to attain their short-term and long-term goals. These attributes are provided through the work of faculty, administrators, and other leaders in arranging such opportunities as research and internship experiences, and as second or junior authors on publications.

The legacy leaders cited in McGee's study intentionally create a supportive and culturally affirming educational culture for Black students which includes ensuring student internships, study abroad experiences, and research opportunities. Other factors include good academic advising, access to caring faculty mentors, peer mentoring, and student financial aid. All these programs require leaders at every level who can advocate for students and who can generate financial and other resources to consistently sustain them.

Leaders' skills in building and nurturing external networks, particularly, are often essential for success in obtaining extramural funding to support STEM faculty and student research, student support programming, facility enhancements, and faculty development. Administrators at all levels can have a significant role in fostering partnerships with other institutions and organizations which may offer research opportunities, laboratory resources, and programs that provide students with pathways to STEM careers. For example, the NSF-funded project on polymer research documented by Orozco and colleagues involved multiple institutions and resulted in increasing the technical skills and success-oriented behaviors of participating undergraduates. The study documents the impact of participation in research on student skills, knowledge, and aspirations.

Collaborative leaders may form networks with high schools to identify potential STEM recruits and provide enrichment activities such as summer programs, social action, and leadership development. At the graduate level, leadership of support activities may include mentoring and preparation for Ph.D. programs, as well as cultivation of internships and research experiences in professional settings outside universities.

For structural initiatives to succeed, leaders extending from the presidents to STEM faculty and staff must commit to an institutional STEM agenda and its STEM community. Inclusive leadership for STEM may involve provosts leading from the middle and including an invitation to faculty voices across disciplines. Similarly, leaders must provide inspiration and motivation for cross-disciplinary programs and activities which reflect an institution-wide STEM-aligned learning environment.

The articles in this special issue of JNE offer a holistic, systemic perspective on leadership in support of diversity, equity, and inclusion in STEM. Cultural attunement, shared values, and commitment to a common vision inform the practices, programs, and experiences documented herein. STEM Leadership Matters!

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