Institutional and Leadership Predictors of HBCU Success in Broadening Participation in STEM

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Historically Black colleges and universities (HBCUs) are noted for their success in broadening participation in science, technology, engineering, and mathematics (STEM). A multiple case study approach was used to identify institutional and leadership characteristics that may drive the success of small HBCUs in broadening participation in STEM. Data on 15 HBCUs were obtained from websites, including institutional websites, and the Integrated Postsecondary Education Data System (IPEDS). Factors common to many institutions included external STEM education funding, STEM-/research-focused missions, commitment of leaders to STEM education, partnerships to support STEM education, STEM faculty professional development, and STEM student support strategies. These characteristics also predicted the percentage of STEM graduates. Implications for future research include illuminating the pathways by which institutional and leadership factors influence student outcomes.

Keywords: *STEM, higher education, case study, HBCU, leadership, broadening participation, student success*

Success in science, technology, engineering, or mathematics (STEM) fields is important for a diverse 21st century workforce that represents the nation's population. According to the Pew Research Center (2018), the STEM workforce has an underrepresentation of women, Black Americans, and Hispanic Americans. Although women account for 50% of all workers in STEM, women are mainly healthcare workers and technicians and rarely in more lucrative engineering and computer fields. Furthermore, Blacks comprise 11% of the overall U.S. workforce but comprise only 9% of the STEM workforce. Likewise, Hispanics represent 16% of the U.S. workforce, but only 7% in STEM fields. Although STEM workers earn a relatively high salary in comparison to many non-STEM workers, an earning gap within STEM fields exists because women, Black Americans, and Hispanic Americans tend to be employed in less lucrative fields (social science and biological science in comparison to computer or information science) than their White counterparts (National Center for Science and Engineering Statistics, 2021).

Historically Black colleges and universities (HBCUs) serve as significant producers of minority STEM graduates. The National Science Foundation (NSF, 2017) noted that Black science and engineering students mainly received their undergraduate degrees from HBCUs; and HBCUs were the degree-awarding institutions for 30% of doctorate recipients. Due to the high percentage of Black STEM graduates, HBCUs are in an advantageous position to broaden participation in STEM (Upton & Tanenbaum, 2014).

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Due to their STEM undergraduate production rate, HBCUs are broadening participation in STEM and contributing to the nation's diverse workforce. Moreover, they are doing so despite the myriad barriers that impact Black students' STEM college readiness and STEM pipeline persistence (Harper, 2018). Physics and calculus courses, as well as college counselors, are not readily available in high schools mainly populated with Black students (Fontana et al., 2020). In the context of these barriers, the purpose of this study was to begin identifying institutional and leadership characteristics of HBCUs that may be associated with their success in broadening participation in STEM.

With the help of federal funding, most notably from NSF and the U.S. Department of Education's Minority Science and Engineering Improvement Program (MSEIP), HBCUs have tested several strategies to increase the recruitment, persistence, and graduation of STEM majors. Research suggests that effective strategies include such factors as early STEM exposure, authentic science engagement both inside and outside of the classroom, active learning, and bridge programs (Institute for Broadening Participation, 2016). These strategies also focus on faculty professional development to increase research productivity (Qazi & Escobar, 2019), and implementation of evidence-based, culturally responsive teaching practices that promote active learning and engagement (Clewell, Cosentino de Cohen, & Tsui, 2010; Ero-Tolliver, 2019). More recently, research has begun to examine strategies to cultivate dispositions that promote the success of U.S. minority students in college and beyond (Park et al., 2018). Dispositions include such factors as a growth mindset, STEM identity, and self-efficacy.

To be sure, research on the proximal activities that promote student success in STEM is essential. However, it is equally important to examine the role that institutional and leadership characteristics play in adopting, supporting, and sustaining such individual-level strategies (Mack et al., 2019). For example, the priorities of leadership add or take away resources from the institutional infrastructure to support STEM education (Taylor & Wynn, 2019) and "set the tone" in which such activities and policies aimed at broadening participation occur (Mack et al., 2019). The limited research on the topic supports the importance of leadership in broadening participation in STEM (e.g., Clavier et al., 2021; Engerman, McKayle, & Blackmon, (2021). Developing a deeper knowledge of these factors and their pathways of influence may be vital to sustaining the impacts of more proximal activities that influence student outcomes.

The purpose of this study was to examine commonalities in institutional and leadership characteristics at small HBCUs to uncover those that may be related to their success in broadening participation in STEM. Scholarship suggests that small HBCUs play a key role in graduating STEM majors, and some are more successful in doing so than their larger peers (Jackson, 2013). Furthermore, the qualities of leadership that predict STEM success at small institutions may differ from those predictive at larger institutions (Boncana, McKayle, Engerman, & Askew, 2021). Furthermore, the study also examined whether variation in these characteristics predicted the percentage of graduates that were STEM majors among these institutions. Understanding the institutional and leadership characteristics of certain HBCUs may predict STEM outcomes. Additionally, this study aimed to provide evidence that can be used to further strengthen the capacity of HBCUs to broaden participation in STEM.

METHOD

This study took an inductive research approach to identify institutional characteristics that could be responsible for HBCU success in broadening participation in STEM, with a particular emphasis on factors that could relate directly or indirectly to institutional leadership. Data were gathered through an iterative process, which resulted in case summaries that described each institution relative to a list of characteristics identified as potential contributors to STEM success. Comparisons were then made across case summaries to identify the characteristics common to the set of institutions. Finally, quantitative analyses were conducted to examine how variability within these characteristics predicted the ability of these institutions to broaden participation in STEM.

Cases

The focus of the study was on 15 HBCUs with enrollments of between 800–2500 students. Eight of the institutions are public institutions and seven are private with religious affiliation. One public institution is affiliated with a religious institution. Two of the HBCUs are land-grant institutions. According to the Carnegie Foundation for the Advancement of Teaching (2018), nine institutions are classified as small; five are classified as very small four-year baccalaureate institutions; one institution is listed as a "Master's Colleges and Universities: Small"; nine of the institutions are in settings classified as mid-sized or large cities; four are in towns; two are in rural settings; and all but one of the schools are classified as residential institutions.

Selectivity of the institutions varies widely. One third of the institutions admit 90% or more applicants, one third admit less than 50% of applicants (range 38%–43%), and the remaining institutions ranged from 56%–71% (National Center for Education Statistics; NCES, 2020). The average in-state tuition costs after financial aid also ranged widely. Nine institutions cost below $15,000 per year, four cost between $15,001 and $25,000 per year, and two cost above $25,000 per year (NCES, 2020).

There was also variation with respect to the overall learning environments at the institutions. Of the 14 baccalaureate programs, Carnegie classifies one-half of them as having an arts and sciences focus and the other half as having a diverse field focus. The schools also vary widely in terms of the percentage of full-time faculty (22%–100%) and student–faculty ratios (9:1-20:1; College Factual, 2020). At 87% of the schools, the percentage of full-time faculty was on par or exceeded the national average of 47%. Similarly, 60% of the schools had student-faculty ratios equal to or above the national average (15:1).

The institutions in the study sample offer majors that fall into 11 STEM areas of study including biomedical science, natural resources and conversation, mathematics and statistics, computer and information sciences, physical sciences, and engineering. The disciplinary areas with the largest degrees conferred in SY2016-17 across institutions was the biological and biomedical sciences (1,056). The area with the smallest degrees conferred was computer and information sciences (11), not to be conflated with computer engineering (75 degrees were conferred in the field of engineering of which computer engineering was included).

Data Collection

The research began with the examination of dossiers prepared by the Center for the Advancement of STEM Leadership (CASL) to aid its researchers. The information in the dossiers was assembled from the institutional websites, newspaper/news blogs, and postings related to special STEM programs. The dossiers included information on the mission/vision of the institution, educational background information on the institution's leadership team, STEM degrees offered by the institution, and special STEM programs. Dossiers included demographic information on the schools, such as the size and type of institution, the campus setting (city, town, rural), and whether the campus was primarily residential. Finally, dossiers included information on overall institutional outcomes, including first-year retention rates and graduation rates at four and six years. Demographic information and institutional outcomes data included in the dossiers were obtained from Integrated Postsecondary Education Data System (IPEDS; NCES, 2020).

First, each dossier was reviewed to identify characteristics that could potentially explain or be related to the institution's success in broadening participation in STEM. This review was guided by the literature on leadership in STEM (Engerman et al., 2021) and the expert knowledge of the research team. For example, dossiers were examined for information related to whether any members of the institutional leadership team had an academic background in a STEM field and the types of programs they offered to support STEM education. Next, a comprehensive list of all of the characteristics identified from the review of the 15 cases was created. These characteristics fell into five broad categories that reflected ways in which the overall institutional environment and its leadership could influence STEM success. These categories included (a) the mission and vision of the institution; (b) the STEM background of the leadership team; (c) the institutional environment with respect to STEM; (d) supports for STEM majors; and (e) supports for STEM pathways prior to college entry and after graduation.

Individual dossiers were then reviewed for completeness with respect to information relevant to the characteristics identified. Additional internet research was conducted on each school where information on the characteristics identified was missing. These included Google searches to identify the educational background of the leadership team that included the name of the school and the word "STEM," as well as searches for the word, "STEM," on the institutional websites. Information about federal grant awards made to schools in the past five years that broaden participation in STEM, was obtained from searches conducted on each funder's website (NSF and the U.S. Department of Education's Minority Science and Engineering Improvement Programs; MSEIP). The five-year timeframe reflected the current STEM school environment.

Additional data about each institution's learning environment, including the percentage of full-time faculty at the school, the student–teacher ratio, and whether the school earned any badges for being in the top 15% of colleges "most focused" for a STEM major, were obtained from College Factual (2020). "Focused" was defined as the percentage of students enrolled in a particular degree program. Those schools ranked as "most focused" for a particular major have a greater percentage of their students enrolled in that major than other schools.

Next, case summaries describing each school relative to the characteristics identified from the initial dossier reviews and those identified during the internet searches were developed.
The case summaries included the following:

- Mission/vision—whether the mission/vision statement for the school mentioned STEM or research
- Leadership team—whether members of the senior leadership team, including the president and provost, had a degree in a STEM field at any level or whether their website bios mentioned a commitment to STEM (e.g., raised money specifically for STEM education, initiating STEM programs, etc.)
- Institutional environment with respect to STEM—the number and overall percentage of STEM majors, College Factual badges earned, partnerships with other institutions of higher education (IHE) or other organizations to extend STEM opportunities, faculty STEM professional development, federal grant awards to support broadening participation in STEM from NSF or the U.S. Department of Education, and whether the school has any STEM research centers or institutes.
- Support for STEM students—whether the school provided research internships or other extracurricular research opportunities, scholarships specifically for STEM majors, bridge programs for incoming STEM majors, or other types of support specific to STEM.
- Support for STEM pathways—whether the school provided outreach or programs related to STEM for K–12 students, professional development for K–12 teachers, and programs to support the pathways of STEM majors, post-graduation.

In addition to examining individual characteristics of the institutions, a qualitative rating from 1–5 was given with respect to each of the five categories that indicated how strongly the institution was committed to STEM in each area. For each category, points 1, 3, and 5 on the scale were anchored with specific criteria needed to obtain the score. Criteria included each of the characteristics that were part of the broader category. An overall qualitative rating was also given to each institution to reflect its overall "intentionality" with respect to broadening participation in STEM (see Table 1 for a description of the commitment ratings).

Finally, using data obtained from the dossiers, the percentage of 2017 STEM graduates was used to assess the success of each school in broadening participation in STEM (NCES, 2020). The difference between the percentage of STEM graduates and the percentage of STEM majors offered out of all possible majors at the school was another metric of success to account for some schools offering more STEM majors, and hence, more likely to have a higher proportion of STEM graduates. As results did not vary by success metric, only those results pertaining to the overall percentage of STEM graduates will be presented.

Data Analysis

The data analysis proceeded in three steps. First, the 15 case summaries were examined for commonalities in characteristics that might explain why HBCUs are more successful generally in broadening participation in STEM. Second, correlational analyses were conducted to examine the relationship between institutional and leadership characteristics, and the percentage of STEM graduates. Finally, exploratory analyses were conducted to examine how institutional characteristics specific to STEM were inter-related, and how these were related to broader institutional characteristics, such as first-year retention rates and percentage of full-time faculty.

Table 1

Scoring of Commitment in Five STEM Categories

Category	1	2	3	4	5
Mission/Vision 1) Mentions STEM 2) Mentions Research	No STEM or research		STEM or research mentioned		STEM and research included
Leadership Team 1) ED background of leadership TEAM 2) Demonstrated commitment to STEM	No educational background in STEM or commitment to STEM		Demonstrates commitment to STEM		Leadership has STEM educational background and commitment to STEM
Institutional Environment with respect to STEM 1) Fed funding with respect to STEM education in past 5 years 2) Has partnerships to expand research and education 3) Offers faculty professional development specific to STEM 4) Has STEM research center or institutes 5) STEM Major is 'most focused'.	No STEM funding No partnerships No PD No STEM research center No STEM major ranked "most focused".		Has fed funding for STEM and at least 1 other feature supportive of STEM		Has fed funding for STEM, Has STEM research institutes/center and at least 1 other feature supportive of STEM
Supports to STEM Students 1) Research/Internships 2) Scholarships/funding 3) STEM bridge program 4) Other	No supports for STEM students		Offers at least two types of supports		Offers research internships; STEM bridge program, and funding
STEM Pathways 1) K-12 students 2) Post-grad 3) K-12 teachers	No programs to promote pathways		Offers at least one program to support pathways		Offers at least two programs to support pathways, which includes post-graduation pathway

Note. STEM = Science, Technology, Engineering and Math; PD = Professional Development; ED = Educational.

RESULTS

Common Institutional Characteristics

Table 2 describes the specific characteristics that were examined across the cases to determine commonalities, and the percentage of schools in which that characteristic was present. Only one characteristic was common across all fifteen schools: each received federal funding from either NSF or MSEIP to promote STEM education. All but one school had received funding from NSF in the past five years.

When looking at the five broad categories, all were applicable with at least one indicator being present for each institution; they, or at least one of their more specific indicators where applicable, were common to at least two-thirds of the schools. Overall, these institutions signaled a commitment to STEM in their mission/vision statements and in the leadership hired to fulfill the institutional mission. Two-thirds of the institutions mentioned STEM or research in their mission or vision statements.

Table 2

Commonality of Institutional and Leadership Characteristics Across Schools

Institutional and Leadership Characteristics	**% of Schools**
Mission/Vision	
Mentions STEM	26.67
Mentions Research	46.67
Mentions STEM or Research	67.67
Leadership Team	
Has educational background in STEM	21.42
Has demonstrated a commitment to STEM	71.43
Has educational background or demonstrated a commitment to STEM	78.57
Institutional STEM Environment	
Received federal funding for STEM education in last 5 years	93.3
Has partnerships to expand STEM opportunities	73.3
Offers faculty professional development in STEM	80.0
Has STEM research center(s) or institute(s)	25.0
STEM major (s) rated as “most focused”	86.7
Supports for STEM Students	
Research opportunities or internships	67.7
Scholarships available specifically for STEM majors	53.3
STEM bridge program offered	26.7
Other student supports	40.0
Offers at least one of supports listed above	86.7
STEM Pathways	
K-12 students	67.7
K-12 teachers	33.3
Post-graduation	40.0
Supports at least of one of the above	67.7

In all but three schools, either the president or the provost, had a degree in and had demonstrated a commitment to STEM. An example of a commitment to STEM included a president, who did not have a STEM educational background, yet was credited with starting a new STEM program. In another case, a provost, who did not have a STEM degree, was the principal investigator on multiple NSF grants aimed to broaden participation in STEM.

In addition to receiving funding for STEM education, the schools shared other characteristics that could be described as promoting an institutional environment conducive to broadening participation in STEM. Perhaps particularly important in relatively small schools with fewer resources, the large majority extended educational and research opportunities for students and faculty by forming partnerships with other institutions. For example, out of those engaged in partnerships, 45% partnered with other IHE to offer 3-2 programs in engineering. Other types of partnerships included those with larger research institutions that facilitated collaborative faculty research through shared facilities and resources, which, in turn, are meant to foster more opportunities for student research. Some schools (27%) partner with non-IHE entities, such as NASA, to facilitate research opportunities for students. The fact that only 26% of the schools had a STEM research center (or institute) made this commonality among the schools even more significant.

There were other commonalities among the schools in terms of their institutional environment with respect to STEM. Except for faculty in one school, STEM faculty were provided professional development opportunities so they could support efforts to broaden student participation in STEM. By and large, these opportunities were funded through grants. All but two schools had at least one STEM field ranked as being among the "most focused" majors according to College Factual (2020). Overall, the schools in the study created institutional environments that were conducive to STEM education.

Most of the schools were also intentional about building STEM pathways. Frequently, these pathways were in the form of outreach to, and programs for, K–12 children in their communities. Additionally, these opportunities included a wide range of activities aimed to stimulate interest in STEM, from Saturday STEM institutes to more intensive residential summer camps. Students were sometimes engaged in the delivery of these activities. Some schools directed outreach activities to teachers of K–12 children, offering various kinds of STEM-related professional development opportunities. Although not as common as building the pipeline into undergraduate institutions, 40% of the schools promoted pathways for their majors beyond college. Some, for example, built bridge programs to graduate programs at other institutions with which they forged partnerships.

Many of the schools provided supports specifically for STEM majors. All but two schools offered at least one type of support to STEM students in the form of research internships/extracurricular research opportunities, scholarships, or bridge programs. More than half of the schools offered two or more support programs to STEM students. Of those that offered STEM programming, nearly all offered internships or other structured research opportunities. About one-half of the schools provided scholarships specific to STEM students.

Finally, as noted in the description of cases, the institutions varied widely in terms of their characteristics. One factor in common to the 15 institutions, was that, apart from two schools, the percentage of full-time faculty was equal to or above the national average.

Characteristics that Predict STEM Success

Although the cases shared many commonalities, there was also substantial variability in their characteristics and the percentage of graduates that were STEM majors (18.5%–74%). This variability gave us the opportunity to use the 15 cases to explore which characteristics were predictive of STEM success in these small HBCUs. The overall ratings on the five categories of institutional characteristics related to STEM were used in these analyses. One-tailed significance tests were used because the sample size was small, and all hypothesized relationships were directional. It was expected that scores indicating a higher commitment to STEM would be related to a higher percentage of STEM graduates.

Table 3 depicts the correlations between the ratings on the five categories of STEM characteristics and the percentage of STEM graduates. As can be seen from the table, three out of the five categories were significantly and positively related to the percentage of students who graduated with a STEM major. These included the ratings pertaining to the background of the leadership team (r_s = .471, p = .044, 95% CI [.113, 1.00), the overall STEM environment (r_s =.565, p = .014, 95% CI [.254, 1.00), and STEM pathways (r_s =.574, p = .013, 95% CI [.266, 1.00]. The STEM Mission (r_s = .359, p = .094, 95% CI [.-.005, 1.00] and STEM Support scores (r_s =.400, p = .070, 95% CI [.043 – 1.00]) tended to be positively related to the percent of STEM graduates. Given these results, it follows that the overall "intentionality" rating was strongly and positively related to the percentage of STEM graduates (r_s = .605, p = .008, 95% CI [.209, 100].

As can also be seen in Table 3, overall institutional characteristics were related to the percentage of STEM graduates. Teacher–student ratios (r = -.606, p = .008, 95% CI [-1.00, -.203] and retention rates (r = .507, p = .027, 95% [.066, 1.00] were significantly correlated with the percentage of STEM graduates. Among institutions with a baccalaureate classification, having an arts and sciences, rather than a diverse fields focus was strongly related to a higher percentage of STEM graduates [r_{pb} =- .678, p = .004, 95% CI [-1.00, -.294].

Table 3

Institutional and Leadership Predictors of STEM Success [a,b]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. % STEM graduates	--													
2. STEM mission/vision	.359′	--												
3. STEM leadership	.471*	.005	--											
4. STEM environment	.565*	.230	.575*	--										
5. STEM pathways	.574*	.062	.619**	.692**	--									
6. STEM supports	.400′	.254	.431*	.642*	.662**	--								
7. Overall intentionality	.605**	.411*	.597*	.824***	.731***	.754***	--							
8. Tuition	-.122	-.453*	.098	.106	.031	.081	.109	--						
9. Acceptance rate	-.367′	-.704**	-.080	-.013	.081	.163	-.143	-.106	--					
10. % Full-time faculty	.250	.323	.277	.130	.360	.262.	.202	.188	-.141	--				
11. Teacher-student ratios	-.606**	-.172	-.556*	-. 756**	-.633**	- .833***	- .869***	-.318	.039	303	--			
12. Retention rate	.507*	.119	.411′	.533*	.430′	.684**	.686**	.218	-.072	.037	-.815*	--		
13. 6-Year graduation rate	.199	.086	.073	.020	-.104	.331	.168	.405′	-.412′	.272	-.377	593**	--	
14. Baccalaureate type	-.678**	-.237	.000	.167	.019	-.074	-.056	-.408′	.515′	.240	.220.	-.181	-.544*	--

Note. * = $p \leq .05$, one-tailed test; ** = $p \leq .01$, one-tailed test; *** $p < .001$, one-tailed test, ′ = $p \leq .10$, one-tailed test. [a] $N = 15$, except for correlations involving the STEM leadership or baccalaureate type variables where $N= 14$; [b] Spearman-Brown correlations reported for tests involving ordinal variables; all other values are Pearson correlations.

Interrelationships among Institutional Characteristics

Relationships among the five STEM ratings were examined, as were relationships between them and more general characteristics of the institution. The aim was to explore possible pathways by which these variables may operate to influence success in broadening participation in STEM. Table 3 depicts the correlations among the scores on the five STEM categories, and between these categories and overall institutional characteristics. As can be seen in the table, scores on the five categories were substantially related to one another but they do not appear to be redundant with one another. For example, STEM Mission was not significantly related to the other four category scores even though it tended to predict STEM success.

As can also be seen in Table 3, teacher–student ratio was negatively associated with positive institutional characteristics related to STEM, including the STEM background of the leadership team, the overall STEM environment, STEM supports to students, and STEM pathways. Student retention rates also demonstrated a similar pattern of relationships to ratings of the five STEM categories.

DISCUSSION

The purpose of this study was to begin identifying institutional and leadership characteristics that could be important in understanding how small HBCUs successfully broaden participation in STEM. Although the list of factors identified for this study is obviously not exhaustive of all characteristics that could be relevant at these institutions, or at larger HBCUs, it does speak to the fact that viewing an institution and its leadership from the perspective of broadening participation in STEM is possible.

The search revealed that the most common characteristic across all 15 cases was being the recipient of NSF or MSEIP funding to support efforts to broaden participation in STEM, and all but one having received this funding in the last five years. Considering both the infrastructure and faculty costs associated with providing quality STEM education, this finding suggests that leaders of smaller HBCUs can prioritize building strong offices of sponsored programs to seek external support for broadening participation in STEM.

The study findings suggested that the institutions had environments conducive to STEM education and research. Most schools made investments in faculty professional development and forged partnerships that expanded STEM opportunities for faculty and students. Both activities may be especially important for leaders of smaller colleges, and particularly HBCUs, where heavy faculty teaching loads can detract from research, publications, and grant writing among early career faculty (Hendrickson & Haynes, 2019; Palmer & Griffin, 2009). Thus, this suggests that effective leadership will prioritize professional development as a strategic investment to support faculty research, which in turn, can help faculty to become effective student research mentors. Relatedly, smaller schools may lack the physical infrastructure and resources to support STEM research among faculty, in which case leaders may forge partnerships with other institutions as critical in supporting faculty research and expanding STEM research and educational opportunities for students.

Grant funding, professional development for faculty, and institutional partnerships do not happen in a vacuum. Nearly 80% of the schools had a leadership team, which by virtue of their own educational background or other activities, demonstrated a commitment to STEM. As there always are competing demands on institutional resources, particularly at smaller colleges and those with less generous endowments, academic leadership must make difficult decisions regarding where institutional resources will go and where efforts to increase these resources should be focused. Two-thirds of the schools had a mission statement that mentioned STEM or research specifically. The mission and its actualization, however, still relies on the vision and activities of the academic leadership team.

It is important to note that while there were some commonalities in institutional characteristics that could help broaden participation STEM, especially when considered at a broad level, the schools were not the same relative to specific priorities that may differ depending on the circumstances at specific schools. For example, the leadership of one institution located in a rural area very deliberately created partnerships with other IHE and research organizations so that students could have easier access to research internships. Other schools with no STEM graduate programs may focus on building STEM pathways for students beyond graduation. Thus, the specific strategies that institutional leaders use to support STEM education must be responsive to individual contexts.

The usefulness of the five categories identified for understanding how institutional and leadership characteristics may impact STEM success was further demonstrated by the ability to predict the percentage of STEM graduates. Although these results should be interpreted with caution because of the sample size, ratings on all five categories demonstrated medium-large to large associations with respect to the percentage of STEM graduates in these institutions. An overall intentionality rating comprised of the average of these five scores also strongly predicted the outcome, suggesting that it may be possible and useful to assess an institution's overall commitment to STEM. More research, however, is needed to establish the psychometric quality of the ratings used in this study and to further substantiate their predictive validity.

IMPLICATIONS

Understanding how HBCUs broaden participation in STEM, and how they can increase their ability to do so, requires examination of both the proximal and distal drivers of students' success in STEM and the contributing role of leadership at all levels. A structure ⇒ process ⇒ outcomes model, used to understand both proximal and distal drivers of children's outcomes in early care and education settings (NICHD ECCRN, 2002), may be useful as a framework for understanding the complex ways in which these factors interact to broaden participation in STEM. In such a model, process variables are those that students experience directly, from their learning experiences inside the classroom to the quality of their interactions with teachers. As such, process variables are most proximal to learning outcomes. Structural variables, in turn, influence these process variables but are not ones with which students are directly engaged. Results from this study suggested structural variables that define the STEM environment and are shaped by institution-wide factors include the school mission and teacher to student ratios. This study contributes to the research by identifying systems-level leverage points that leaders of small HBCU institutions can and do use to broadening participation. Figure 1 depicts a framework for HBCU success in broadening participation in STEM emerging from this study.

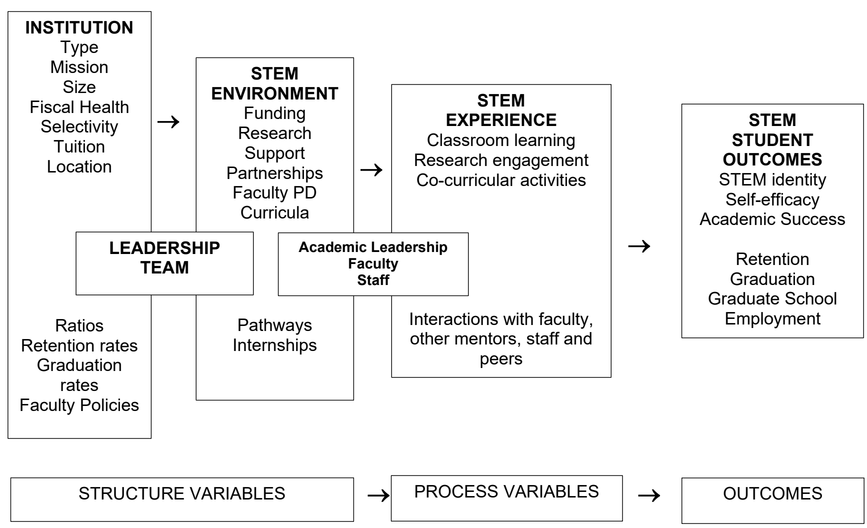

Figure 1. *A Structure → Process → Outcome Framework of HBCU Success in Broadening Participation in STEM.*

Lastly, this study adds to other studies to reinforce that who the leaders are and how they lead matters (Engerman et al., 2021; Mack et al., 2018). In this study, small HBCUs with a leadership team that has demonstrated a commitment to STEM were more successful in broadening participation in STEM. Again, this should not be surprising as the leadership team sets institutional priorities and aligns resources to fulfill those priorities. As illustrated in Figure 1, leaders' decisions affect the overall institutional environment and get enacted by mid-level academic leadership, faculty, and staff, who directly shape student outcomes. The leadership characteristics that encourage and support these pathways merits investigation.

CONCLUSION

Overall, this study has added to the body of literature which has demonstrated that characteristics of HBCU leadership and institutional environments with respect to STEM are important in understanding their roles in broadening participation in STEM (Clavier et al., 2021, Engerman et al., 2021). This study extended the knowledge base by showcasing factors that contribute to the ability of small HBCUs in that effort. These include factors specific to STEM, as well as broader institutional factors.

Future research is needed to understand other institutional and leadership factors that may be relevant in an institution's ability to broaden participation in STEM, even among the institutions that are similar to those in this study. As noted, this study was not designed to elucidate an exhaustive list of such factors. It is hoped that this study will spur other researchers to identify additional factors, suggest ways of measuring them, and discover the pathways by which they exert their influence so that the ability of HBCUs to broaden participation in STEM can be further strengthened.

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