The HBCU Student STEM Success Survey: Developing and Validating a Measure of the Academic, Social and Cultural Experiences of STEM Students at HBCUs

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Historically Black colleges and universities (HBCUs) are important for diversifying the science technology, engineering, and mathematics (STEM) workforce. This study aims to develop a scale to understand the experiences of HBCU STEM students to spur research on the factors associated with HBCUs' success with recruiting, retaining, and graduating Black STEM students. Nearly 3,000 undergraduate STEM students across 30 HBCUs participated in this study. The authors conducted exploratory and confirmatory factor analysis to examine the construct validity. The survey had a seven-factor structure with a comparative fit index of 0.9 and high reliability with Cronbach's alpha ranging from 0.68-0.91. Five factors significantly predicted student outcomes, indicating predictive validity. The resulting survey, HBCU Student STEM Success Survey, provides a reliable and valid measure for HBCU STEM students' experiences.

Keywords: *STEM Succes Survey, HBCU STEM students, STEM opportunities, STEM recruitment and retention*

Little empirical information is available about the academic and sociocultural experiences of HBCU STEM students. This study aims to develop a scale to understand the experiences of STEM students at HBCUs to spur more rigorous research on the academic, social, and cultural factors associated with HBCUs' success with recruiting, retaining, and graduating Black STEM students. Historically Black colleges and universities (HBCUs) enrich the lives of Black Americans by expanding opportunities and imparting knowledge. HBCUs contribute to the national need for a diverse science, technology, engineering, and mathematics (STEM) talent by preparing underrepresented students, primarily African Americans, for these professions (Toldson, 2019). HBCUs are pivotal in helping expand careers in STEM disciplines nationally (Toldson, 2013). According to a report by the National Science Foundation and the National Center for Science and Engineering Statistics (2019), 25% of Ph.D. recipients in science and engineering from 2013 to 2017 received their undergraduate degrees at HBCUs.

HBCUs admit students with diverse backgrounds, varying levels of academic preparation (e.g., lower GPAs and GRE scores), and underrepresented students, "yet these students are more likely to earn degrees in STEM disciplines" (Lane, 2015, p..10). Black students who attend HBCUs succeed and matriculate in STEM majors at a higher rate than their counterparts at predominantly White institutions (PWIs) (Eagan et al., 2010). Like students of other races, African American students elect to pursue their STEM education at HBCUs because of factors such as early exposure to STEM fields, familial and scholars' support, and enriching experiences in science (Hayes, 2012; Toldson,

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2018, 2019). However, HBCUs offer teaching and learning experiences for Black students that differ from PWIs (Whaley, 2012).

According to Rankins (2019), HBCUs are successful with educating Black STEM students because of the institutions' ability to allow students to "live their best and authentic lives." Also, HBCUs are unique in that students in STEM fields benefit from engaging with faculty role models (Adams et al., 2017; Toldson, 2019) who respect their views and contributions (Gasman & Nguyen, 2014). It is therefore imperative to learn from these institutions about the practices that have made them successful in educating STEM students. In the next section, we review literature on factors that contribute to STEM student success at HBCUs. These studies provide vital information to develop the content necessary to develop a survey to explore academic and sociocultural experiences of HBCU STEM students.

LITERATURE REVIEW

Institutional Culture

HBCUs share a primary mission of providing access to higher education and expanding educational opportunities for disadvantaged communities (Jett, 2013); a mission that has demonstrated effectiveness with historically marginalized STEM populations (Capers & Way, 2015; Hurtado et al., 2011; Toldson, 2018). The mission of HBCUs influences the educational environment in which learning occurs and drives the enactment of culturally informed practices (Darrell et al., 2016). In alignment with their mission, HBCUs offer culturally relevant pedagogy, programs, and practices to its students (Allen et al., 2007). The institutional culture related to nurturing environments, strong community connections, close relationships with peers, and meaningful faculty interactions among STEM majors at HBCUs (Gasman & Palmer 2008) influences the experiences and holistic success of Black students at HBCUs. This sense of community is core to HBCUs' organizational culture. HBCUs provide students with a unique cultural community that affirms their value and sense of belonging.

There is empirical evidence that shows that HBCUs provide a warm, welcoming, nurturing, family-oriented environment that promotes Black students' self-efficacy, racial identity, social and psychological well-being, academic performance, and persistence (Gasman & Palmer, 2008; Reeder & Schmitt, 2013). When STEM students attend a school where they are outnumbered in their racial composition, they may not participate in activities because of feeling a sense of discomfort and never get a genuine sense of belonging (Winkle-Wagner & McCoy, 2018). Black students feel HBCUs provide better environments for them as they are comfortable attending school where they are the critical mass (Torromeo, 2019). At HBCUs, students are in an atmosphere where they are likely to experience positive racial identities and embrace cultural awareness (Campbell et al., 2019).

STEM Learning Environments at HBCUs that Foster Student Success

Research shows that institutional environment plays an integral role in Black student persistence and success in STEM disciplines. Compared to other academic institutions, HBCUs have traditionally provided more inclusive and nurturing campus environments to their STEM students (Harper & Antonio, 2008; Kendricks et al., 2013). HBCUs have a unique understanding of the diverse backgrounds and educational needs of Black students in STEM and provide supportive environments that give these students every opportunity to excel (Kendricks et al., 2013). As reported by Harper and others (2004) and Perna and colleagues (2009), despite limited resources, HBCUs offer learning environments that prepare African American STEM students for success.

According to Gasman and Nguyen (2014) potential influential characteristics of the HBCU environment that successfully support STEM students are the institutions' belief in the ability of Black students and a climate that celebrates participation and achievements. Having a culture that affirms HBCU students' ability is critical in promoting student success in STEM.

HBCUs use a range of social and academic approaches, including providing adequate financial support, faculty mentoring and involvement, peer support, academic support services, and undergraduate research opportunities to enhance the learning experiences of Black students (Gasman & Nguyen, 2014; Perna et al., 2009). Also, many HBCU students benefit from small STEM class sizes that allow them to enjoy meaningful interactions with faculty (Gasman & Nguyen, 2014). The small class sizes allow for close contact and opportunities to work one-on-one with faculty (Villa et al., 2011). According to Toldson (2013), STEM students at HBCUs report enjoying positive relationships with the faculty and being satisfied with the learning environment at their campuses. These supportive environments, along with the culture and mission of HBCUs are foundational to these institutions' contribution to the successful production of Black scientists.

Relationships (Faculty–Students/Peer Support)

Student–faculty interaction is an essential component in increasing social and academic integration (Pascarella & Terenzini, 2005; Villa et al., 2011). Compared to Black students attending PWIs, students at HBCUs are significantly more likely to experience positive relationships with their faculty (Hurtado et al., 2011; Toldson & Esters, 2012). Students at HBCUs feel that their faculty members are sensitive to their academic needs, cultural background, and aspirations and that they are readily available and approachable to answer any questions students may have (Toldson & Esters, 2012). Within STEM disciplines, the role of faculty in assisting students to navigate through these academic programs is even more critical (McCoy et al., 2017). Students at HBCUs reported that the guidance they received from faculty encouraged them to enter STEM disciplines (McCoy et al., 2017). STEM students at HBCUs reported their professors make sure they are accessible inside and outside the classroom (Carter & Fountaine, 2012; Fries-Bitt et al., 2010). Strayhorn and Terrell (2007) found that positive faculty–student interactions at HBCUs lead to enriched mentoring experiences. At HBCUs, faculty members are role models who nurture students in their personal and professional lives (Carter & Fountaine, 2012). HBCUs foster an environment where frequent positive interactions between students and faculty occur (Avery, 2009; Gasman & Palmer, 2008). Hylton (2013) found that the frequency of student–faculty interaction supports students' academic achievement and satisfaction with the college experience.

Students who attend HBCUs not only enjoy closer relationships with faculty but also with their peers (Stewart et al., 2008). According to Gasman and Palmer (2008), peer support plays an important role in helping Black students to persist and flourish in their social and academic endeavors. Students reported drawing inspiration to do well from their peers who were doing well academically. According to Gasman and Nguyen (2014), Black students in the STEM fields perform well when they have positive peer relationships. In their study, Perna and associates (2009) reported that HBCU students held each other accountable, which created a sense of obligation to do the best not just for themselves but for each other and ultimately for the benefit of the society. Having peers with similar college experiences is instrumental in students encouraging each other to persist through issues, and in leaning on each other for academic support (Brooks, 2011).

Involvement in STEM-Enrichment Programs

Research shows that student involvement and participation in campus activities, such as student organizations, is crucial to their successful transition and immersion into the campus community (Carter & Fountaine, 2012; Kuh et al., 2000). Karemera and others (2003) found that Black students perform better and are content with school if they receive supportive academic services such as sufficient classroom facilities, research opportunities, and access to computers. HBCU students reported they got recommendations from their faculty to participate in enrichment events outside of class such as academic organizations and lectures series (Carter & Fountaine, 2012).

STEM enrichment programs represent one mechanism that has bolstered the achievement of underrepresented students. These programs often involve coordinated academic support in academic advising, mentoring, and tutoring (Tsui, 2007). Other common supports include STEM organizations, tutoring services, internships, research opportunities, scholarship programs, service learning, first-year seminars, and so forth (Tsui, 2007). Research shows that early exposure of minority students to research opportunities increases their likelihood of graduating with a STEM degree (Fakayode, 2014). They can achieve this through implementing summer bridge programs to improve minority student admissions and retention. Decades of research on the effects of the summer bridge programs at various institutions revealed consistent findings that suggest that program participants, compared to non-participants, are more apt to achieve positive outcomes such as persistence into their second college year in STEM (Bir & Myrick, 2015; Cromley et al., 2016; Evans, 1999; Garcia, 1991; Pascarella & Terenzini, 2005; Sablan, 2014).

Undergraduate research experiences enhance students' progression, retention, and graduation rates at HBCUs among STEM students (Fakayode, 2014; Owerbach & Oyekan, 2015). Early exposure to authentic research experiences increases students' positive attitudes and interests toward research activities and increased awareness of research efficacy in STEM fields (Erebholo & Ero-Tolliver, 2021). In a study by Owerbach and Oyekan (2015) at Texas Southern University, students who participated in research activities during freshman year had significantly higher GPAs than their counterparts who did not have research experiences.

Previous literature has identified the various components which promote minority student success in a college setting, thus informing critical elements of the student engagement and retention initiatives (Tsui, 2007). The literature suggests that enjoying a sense of belonging that arise from authentic connections with others in the university and to the university, is a core element of minority student success (Hausmann et al., 2009; Hurtado & Carter, 1997; Lane 2016; Strayhorn, 2012).

STEM students with developed sense of identity who are more apt to identify themselves as scientists are more likely to persist (Chemers et al., 2011; Eagan et al., 2013; Hurtado et al., 2011; Lane, 2016; Piatt et al., 2019). Other studies have examined an ethic of care (e.g., caring relationships can help to support student achievement) as a guiding practice in intervention programs for underrepresented groups (Lane, 2016; Manning et al., 2006). Lane (2016) also discussed the necessity for proactive care, which is a rigorous advising approach that provides students with the competences to overcome potential challenges related to their academic, social, or personal achievement. This is more beneficial for identifying innovative and complex ways to measure student outcomes and success, acquiring and sustaining funding, and addressing accountability from institutional and national funding sources.

Gaps in the Literature

The literature highlights many unifying features that appear to be related to HBCUs successfully preparing and graduating underrepresented minority students in STEM. However, there are many unanswered questions. For instance, many of these studies observed the typical practices and policies of HBCUs, without clearly indicating if the practices occur naturally because of African American cultural nuances, or strategically to accommodate their students. In addition, analyses of institutional and student characteristics reveal vast diversity among HBCUs' institutional characteristics (Simms & Bock, 2014). It is not completely clear whether variation in the success of HBCUs is a function of lack of knowledge transfer between institutions, or because of resource differences between the higher-performing HBCUs and the HBCUs with lower performance levels. This study aims to develop a survey to understand the experiences of STEM students at HBCUs to spur more rigorous research on the academic, social, and cultural factors associated with HBCUs' success with recruiting, retaining and graduating Black STEM students.

METHOD

Procedure and Participants

The research team used the following methods to identify and recruit HBCUs to participate in the study. First, the researchers selected 21 HBCUs that appeared on the National Science Foundation (NSF) list of institutions that are among the nations' top producers of Black baccalaureate recipients who subsequently complete a doctorate in science and engineering. In addition, the research team identified other HBCUs that are similar to these 21 institutions based on scoring 25 institutional variables such as enrollment size, graduation rate, selectivity, and admission yield.

The scoring system assigned a score to each HBCU based on its proximity to the average for the 21 NSF-identified top producers (referred to here as anchor institutions). For instance, if the average enrollment size for all anchor institutions is 5,000 and the standard deviation is 2,000, institutions that were one (or more) standard deviation below the average received a score of 0; institutions that were within one standard deviation of the average received a score of 1; and institutions that were one (or more) standard deviation above the average received a score of 2. Next, the total score for each institution based on the 25 variables was tallied and the top 13 institutions that were most like the anchor institutions were identified as emerging institutions.

The participants in this study were students at 30 HBCUs. Faculty members collaborated with the research team by serving as liaisons and recruited students majoring in STEM fields. Researchers administered the survey via the web link in three waves during the spring 2019, fall 2019 and spring 2020. STEM fields are defined as majors in engineering, technology, life sciences, mathematics, computer sciences, physical sciences and earth sciences, and social sciences.

Research team members at American Institutes for Research programmed the survey questionnaire as an online data collection instrument using Illume platform and shared the survey link with each site liaison. Research team members from the Quality Education for Minorities Network (QEM) provided site liaisons with recruitment flyers that they distributed at their institutions to increase awareness about the project and encourage participation. Site liaisons also identified student influencers at their campuses that could encourage STEM students to participate.

Survey Development

The research team initially developed the HBCU Student STEM Success (HBCU-SSS) Survey by adapting the Minority Male STEM Initiative (MMSI) Campus Survey. The MMSI Campus Survey was developed in 2010 based on a comprehensive review of the research literature regarding the effects of college on STEM student development (Toldson & Esters, 2012). They constructed items for the MMSI Campus Survey—using previous research, broadening participation programs, and best practices information—to obtain critical data regarding students' perceptions of their academic experiences and students' views of the campus climate. During the item development process, researchers generated items that represented the issues, challenges, and opportunities experienced by minority males in STEM disciplines. The MMSI Campus Survey included 28 demographic and background information items, 26 perceptions of the classroom and university items, and 38 participation in programs, services, and academic support opportunities items. Researcher based analyses of the MMSI on 1,443 completed surveys across 14 institutions, including 3 HBCUs (Toldson & Esters, 2012).

For the current study, an interdisciplinary and cross-agency research team further examined the literature to adapt the MMSI Survey to use for HBCU research. The common themes regarding HBCU success with preparing STEM students from the literature included:

- HBCUs have a unique structure that could foster a more supportive environment for STEM students,
- HBCUs have developed policies and practices to accommodate and advance STEM students with less academic preparation and resources, and
- HBCUs use of culturally relevant pedagogical approaches foster the academic success of STEM students.

These themes informed the research team when retaining, modifying, and removing items from the MMSI Survey to create the HBCU-SSS Survey.

After developing the initial draft of the survey, the research team recruited four national leaders on HBCUs to review and provide feedback on the survey content. The reviewers included a former HBCU president, an HBCU provost, and two experts on institutional theory and STEM achievement at HBCUs. After incorporating the feedback from reviewers, we administered the survey to a national sample of HBCU STEM students for psychometric validation. Although 2,900 students took the survey, the analytic sample for this survey was 2,066 cases because results were omitted from students with missing data on more than one-half of the items for each factor. We also excluded students that report they had not taken any STEM classes.

Analysis Plan

We conducted both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to identify underlying factor structures of the HBCU-SSS Survey items. Also, the Cronbach's alpha analysis was conducted to compute internal consistency reliability. First, the analytic sample (n = 2066) was split randomly into two groups. Using the first sample, the EFA was conducted, while we used the second sample for CFA. The Cronbach's alpha analysis was conducted on both samples.

Cronbach's alpha estimates were used to assess reliability. To create each index used for the factor composites, the items were first grouped into the factors they corresponded to. We coded each item from 0 to 4, depending on the number of response options. We then averaged together the items that corresponded to each factor to get an overall factor score for each respondent.

We conducted regression analysis on select outcomes measured by the survey. The two outcomes that were predicted were (a) overall GPA and (b) reported likelihood of leaving the institution. The survey tool asked students to report on their overall grade point average (GPA) for the past semester. In addition, the instrument also asked whether the student has considered leaving the institution using a 5-point Likert scale with the response options of strongly disagree, disagree, neither agree nor disagree, disagree, and strongly agree.

RESULTS

Exploratory Factor Analysis

Exploratory factor analysis of the 53 survey items, based on the random split of the analytic sample yielded several solutions. The study team retained a 7-factor solution that seemed to fit the data well with few cross-loadings over 0.35. The comparative fit index (CFI), Tucker-Lewis index (TLI) and the root mean square error of approximation (RMSEA) were 0.904, 0.871, and 0.076, respectively. In this solution, there were seven factors that were identified: (a) student perception, (b) classroom interaction, (c) recruitment and retention, (d) opportunities, (e) success strategies, (f) adjustment, and (g) barriers.

Confirmatory Factor Analysis

The final CFA posited seven factors based on 48 items, five fewer than used for the EFA analyses. One item from the classroom interaction factor structure was excluded (Q14_4), one item from the support factor structure was excluded (Q23_6), and three items from the barriers factor structure were excluded (Q13_8, Q14_5 and Q15_1). These items were excluded from the analysis because including them lowered the overall factor composite score reliability.

This model fit the data reasonably well with RMSEA of 0.088 and CFI and TLI of 0.870 and 0.862, respectively (Values of RMSEA that are smaller than 0.06, and values for TLI & CFI that are greater than 0.90 , represent good model fit; Hu & Bentler, 1999). In summary, the seven factors posited for the CFA analysis were

1. The *perception factor* comprises seven items that measure the students' perception of their school environment and the sense of belonging they experience while they are at the university.
2. The *classroom interaction* factor comprises eight items that measure the nature of classroom interactions with professors and peers. It also includes items that ask about the positivity of the interaction students have with their professions specifically in STEM courses.
3. The *recruitment and retention factor* comprises six items that assess the efforts made by the institution in recruiting and retaining students into the STEM field.

4. The *STEM opportunities factor* comprises six items that evaluate the availability of appropriate opportunities to work with faculty members, to attend conferences, and to gain internship information.
5. The *success strategies factor* comprises nine items that ask if students are aware of the requirements for their study and their approach towards physical, mental, and spiritual health.
6. The *adjustment factor* comprises nine items assessing the ease with which students are adjusting to the school environment and dealing with socioemotional aspects such as racism and sexism.
7. The *barriers factor* has three items that evaluate factors that might have been a barrier to students' access to STEM opportunities.

Refer to Table 1 for more details on the CFA.

All factors except the barriers factor have items that are on a 5-point Likert scale, with the response options of *strongly disagree, disagree, neither agree or disagree, disagree*, and *strongly agree*. The barriers factor had items on a 5-point Likert scale, with the response options of *very difficult*, *difficult*, *not easy or difficult*, *easy*, and *very easy*.

Reliability

The alpha values for the seven factors ranged from .68 (Barrier) to .91 (Classroom interactions). Besides the two factor composites mentioned, the rest of the factor composites had reliabilities in the .80s. All are in the acceptable range (Cronbach, 1951). Table 2 displays the reliability for the CFA factor structure. Table 3 shows the intercorrelation among the seven factors. The factors measuring perception and classroom interactions showed the strongest correlation: .78. Other correlations that were moderately strong included perception and opportunity (0.60), effort for recruitment and retention and classroom interactions (0.67), and success and opportunity (0.67). Barriers showed the weakest correlations, ranging from 0.270 to 0.072.

Predictive Validity

The multilinear regression analysis predicting the reported GPA for students using the identified seven-factor CFA structure showed that only the factor *STEM opportunities* was significantly related to the outcome of GPA when holding the other factors constant. Results are shown in Table 5. The direction of the relationship indicates that when students agreed more to having access to STEM opportunities their GPAs were reported to be higher.

The multilinear regression analysis predicting the reported likelihood of leaving the institution showed that all factors except *success strategies* were significantly related to the outcome as shown in Table 6. The results show that when students have a negative perception of the institution, when the recruitment and retainment strategies were not strong, when STEM opportunities were less available or when barriers were present the predicted likelihood of leaving the institution was higher at the 5 percent significance level. Adjustment to the institution was also related positively to the outcome at the 10 percent significance level. The results show that even when positive classroom interactions are present, if the other predictors are held constant, the reported likelihood of leaving the institution could still be higher. Taken together, the results suggest the factor structure identified by the CFA has predictive validity.

Table 1

Confirmatory Factor Analysis Seven Factor Solution

Model fit indices		CFA 7 factor solution						
Root Mean Square Error of Approximation		**0.088**						
Comparative Fit Index		**0.870**						
Tucker-Lewis Index		**0.862**						
Variable Name	**Variable Description**	**Perception**	**CI**	**RR**	**Opp**	**Success**	**Adjust**	**Barrier**
Q13_1	In general, the campus environment is welcoming to me and people like me.	0.801						
Q13_2	I feel a sense of belonging on campus.	0.822						
Q13_3	I feel someone on campus would miss me if I left the institution.	0.648						
Q13_4	I feel supported by faculty in my major department/program.	0.865						
Q13_5	Faculty include diverse experiences and views in course readings, assignments, or discussions.	0.830						
Q13_6	I feel supported by the administrators/staff in my major school/college.	0.888						
Q13_7	I would choose this same college/university again.	0.787						
Q14_1	Overall, I enjoy my STEM courses.		0.807					
Q14_2	Overall, my interactions with STEM faculty members has been positive.		0.837					
Q14_3	I feel support from my peers in STEM courses.		0.765					
Q15_2	My professors are available/approachable when I have questions		0.839					
Q15_3	My professors encourage me to seek help when needed		0.859					
Q15_4	My professors are sensitive to my academic needs		0.815					
Q15_5	My professors are sensitive to my cultural background		0.714					
Q15_2	My professors are supportive of my academic aspirations		0.870					
Q17_1	My institution does a good job of recruiting students in STEM			0.858				
Q17_2	My institution does a good job of graduating students in STEM			0.725				
Q17_3	Top leadership is committed to recruiting students in STEM			0.964				
Q17_4	Top leadership is committed to graduating students in STEM			0.771				
Q17_5	Adequate resources are dedicated to recruiting students in STEM			0.902				
Q17_6	Adequate resources are dedicated to graduating students in STEM			0.747				
Q20_1	I have appropriate opportunities to work with faculty on research teams or projects.				0.785			
Q20_2	I have appropriate exposure to science internship information.				0.782			
Q20_3	I receive support from faculty to attend science, engineering, technology, or math conferences.				0.836			
Q20_4	I know faculty members who would write me a recommendation for an internship or graduate school.				0.816			
Q20_5	If I was overwhelmed or had doubts about my current major, I know at least one faculty or staff member I could ask for help.				0.848			
Q20_6	I know the specific requirements to succeed academically as a STEM major.				0.851			
Q22_1	I am aware of the academic requirements to graduate with a degree in STEM					0.832		
Q22_2	I have control over the time frame within which I graduate					0.745		
Q22_3	I know what it takes to succeed					0.864		

Model fit indices		**CFA 7 factor solution**						
Root Mean Square Error of Approximation		**0.088**						
Comparative Fit Index		**0.870**						
Tucker-Lewis Index		**0.862**						
Variable Name	**Variable Description**	**Perception**	**CI**	**RR**	**Opp**	**Success**	**Adjust**	**Barrier**
Q22_4	I make good use of available campus resources					0.772		
Q22_5	I am self-directed/motivated					0.817		
Q22_6	I take care of my physical health					0.804		
Q22_7	I take care of my mental health					0.865		
Q22_8	I am attentive to my spiritual health					0.838		
Q22_9	I use social action or activism to achieve my goals.					0.663		
Q23_1	Meeting the academic requirements for major						0.603	
Q23_2	Adjusting to the social environment						0.662	
Q23_3	Negotiating the administrative systems						0.711	
Q23_4	Interacting with faculty						0.888	
Q23_5	Interacting with peers						0.724	
Q23_7	Managing my own schedule						0.605	
Q23_8	Dealing with racism						0.820	
Q23_9	Dealing with sexism						0.832	
Q23_10	Dealing with other social injustices						0.845	
Q15_6	My professors perceive me or interact with me differently than other STEM students							0.647
Q20_7	My race/culture can limit STEM opportunities available to me.							0.961
Q20_8	My gender can limit STEM opportunities available to me.							0.823

Note. All correlations are significant, $p < .01$. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier = Barriers.

Table 2

Reliability for the Exploratory Factor Analysis Factor Structure

	7 factor reliability EFA						
	Perception	**CI**	**RR**	**Opp**	**Success**	**Adjust**	**Barrier**
Alpha r	0.89	0.90	0.84	0.88	0.89	0.85	0.66

Note. All correlations are significant, $p < .01$. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier = Barriers.

Table 3

Reliability for the Confirmatory Factor Analysis Factor Structure

	7 factor reliability CFA						
	Perception	**CI**	**RR**	**Opp**	**Success**	**Adjust**	**Barrier**
Alpha r	0.89	0.91	0.84	0.89	0.89	0.86	0.68

Note. All correlations are significant, $p < .01$. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier = Barriers.

Table 4

Correlations for Confirmatory Factor Analysis Factor Structure

	Perception	**CI**	**RR**	**Opp**	**Success**	**Adjust**	**Barrier**
Perception	1.00						
CI	0.78	1.00					
RR	0.44	0.49	1.00				
Opp	0.60	0.67	0.40	1.00			
Success	0.52	0.56	0.33	0.67	1.00		
Adjust	0.44	0.49	0.22	0.50	0.51	1.00	
Barrier	0.16	0.27	0.13	0.21	0.15	0.07	1.00

Note. All correlations are significant, $p < .01$. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier= Barriers.

Table 5

Linear Regression Output Predicting Overall GPA with Seven-Factor CFA Structure

	Coefficient	**Standard error**	***t*-statistic**	***p*-value**	**[95% Confidence**	**Interval]**
Perception	0.003	0.056	0.06	0.951	-0.10665	0.113528
CI	-0.073	0.068	-1.08	0.278	-0.20621	0.059354
RR	0.010	0.028	0.35	0.726	-0.04504	0.0646
Opp	0.250	0.056	4.45	0	0.139645	0.360046
Success	-0.006	0.060	-0.11	0.915	-0.12376	0.111011
Adjust	0.053	0.055	0.96	0.335	-0.05495	0.16111
Barrier	0.029	0.034	0.85	0.393	-0.03781	0.096082
_constant	3.879	0.170	22.77	0	3.544453	4.212643

Note. Number of observation = 1488, $F(7,1480) = 5.23$; Prob > F = 0; R-squared = 0.0242. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier= Barriers.

Table 6

Linear Regression Output Predicting Students Reported Likelihood of Leaving the Institution with Seven-Factor CFA Structure

	Coefficient	Standard error	*t*-statistic	*p*-value	[95% Confidence	Interval]
Perception	-0.380	0.051	-7.400	0.000	-0.481	-0.279
CI	0.164	0.060	2.740	0.006	0.047	0.282
RR	-0.095	0.025	-3.850	0.000	-0.144	-0.047
Opp	-0.151	0.050	-3.000	0.003	-0.249	-0.052
Success	-0.059	0.054	-1.100	0.271	-0.164	0.046
Adjust	-0.095	0.049	-1.950	0.052	-0.191	0.001
Barrier	0.368	0.030	12.290	0.000	0.310	0.427
_constant	2.968	0.151	19.610	0.000	2.671	3.265

Note. Number of observation = 2060, $F(7,2053) = 45.92$; Prob > $F = 0$; R-squared = 0.1354. Perception = Perceptions of the university; CI = Interactions in the classroom; RR = Recruiting/graduating students of color; Opp = STEM opportunities; Success = Strategies for success; Adjust = Adjustment; Barrier= Barriers.

DISCUSSION

The purpose of this study was to develop a scale to understand the experiences of STEM students at HBCUs. Through a literature review, we found many studies on the institutional culture and learning environment of HBCUs that explain why HBCUs are successful with graduating STEM students. Many of the studies compared HBCU practices and policies to PWIs; however, there are differences among HBCUs with respect to graduation rates and other performance measures. The common experiences of students at HBCUs need to be observed across institutions to understand whether HBCU practices occur organically or strategically. A valid and reliable instrument is necessary for researchers to explore the academic, social, and cultural factors associated with HBCUs' success with Black STEM students across HBCUs.

Nearly 3,000 undergraduate STEM students across 30 HBCUs participated in this study. We conducted exploratory factor analysis and confirmatory factor analysis to examine the construct validity. Factor analyses revealed seven unique underlying factors that describe HBCU STEM students' experiences: (a) the students' perception of the school environment, including their sense of belonging; (b) the nature of the students' interactions with their peers and professors; (c) the students' awareness of the institutions efforts to recruit and retain STEM students; (d) the students' knowledge of opportunities to advance in STEM beyond the class; (e) the extent to which students used holistic strategies to be successful; (f) the students' ability to adjust and cope with difficult socioemotional stressors, including racism and sexism; and (g) the reported presence of barriers to the students' opportunities to advance in STEM. The seven factors captured many aspects of students' experiences pursuing a STEM degree at an HBCU that are related to findings from articles we reviewed for this study. Many of the known cognitive, sociocultural, interpersonal, and humanistic aspects of success are reflected in the survey construct.

Central to validation, each of these factors should contribute to HBCU students being successful in STEM. To estimate the predictive validity, we selected two outcome measures from the demographic questionnaire: grades and connection to the institution. Grades were measured by the students' reported GPA and connection to institution was measured by asking the students if they wanted to leave the institution. The resulting survey was stronger for predicting the students' connection to the institution than the students' grades. Of the seven factors, the only factor that predicted higher grades measured students reported opportunities to gain experience in STEM outside of the classroom, including conference presentations and internships.

Regression analysis revealed that five factors significantly predicted connection to the institution. HBCU STEM students are less likely to leave when they have

- a positive perception of the institution,
- facilitative classroom interactions,
- holistic strategies for success,
- opportunities outside of the classroom, and
- are aware of institutional efforts to recruit and retain STEM students.

Overall, the resulting survey, the HBCU-SSS, provides a reliable and valid way to measure STEM students' experiences at HBCUs.

Several limitations should be considered in the context of the findings. First, the survey used self-report ratings from college students. The length of the test could lead to some fatigue among test-takers, risking common concerns such as yea-saying and central tendency bias. Also, although the survey was anonymous, some students may have used impression management attempts when responding to questions about their performance. Using qualitative results, such as focus groups, to inform findings could add more depth to the results. Second, the outcome variables selected for the regression analysis may not cover the range of outcomes important to HBCU students. The HBCU-SSS measured connections to the institutions better than grades which may suggest and a relationship between grades and the overall collegiate experiences that is unique at HBCUs. In other words, at an HBCU, a students' grades may not be the best predictor of their overall growth experience. Finally, the survey measured aspects of STEM success that have been established in mainstream literature, but a deeper cross-cultural analysis of STEM success in an African American context is necessary to further refine the instrument.

The research evidence observed in this study indicates that the HBCU-SSS is a valid and reliable way to understand the academic, social, and cultural experiences of STEM students at HBCUs. Future studies using the HBCU-SSS can compare differences in the experiences of subgroups of HBCU students and different institutions, as well as discover predictors of STEM success at HBCUs. Findings from such studies can help HBCU leaders develop programs and practices that can spur success in STEM among HBCU students. HBCUs are important to national strategies to diversifying the STEM workforce. Therefore, developing and standardizing tools to gain a better understanding of HBCUs' strengths, challenges, and opportunities for Black STEM students is essential for the long-term development of HBCUs and the future productivity of the United States.

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