An Assessment of HBCU STEM Student Experiences: Towards the Development of a Student Persistence Model

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Abstract

Students pursuing STEM (Science, Technology, Engineering, and Math) degrees at HBCUs (Historically Black Colleges and Universities) may face difficult challenges in their journey to successfully complete their degrees. To address these challenges, it is important to identify problematic areas as well as needed areas of improvement in STEM programs, particularly engineering programs from student, faculty, and administrator perspectives. The purpose of the present research study is to identify barriers that may hinder students from the successful completion of a degree in STEM, such as Engineering by identifying common themes experienced in STEM programs at HBCUs.

A 24-item survey was developed from current literature and administered to current students, faculty, and administrators at HBCUs nationwide to gain insight into undergraduate student experiences in STEM (Terenzi & Reason, 2005; Seymour 2000). The survey items were carefully developed and categorized using 3 strategic and fundamental research thrusts, such as cultural intersectionality; institutional climate; and Engineering career trajectory to support efforts in broadening participation and student persistence. Thus, the survey elicited responses from students, faculty, and administrators based on these 3 areas. Participants were asked to rate items centered on their experiences and perspectives in their current STEM degree programs using a Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree, 6 = Not Sure). The participants were from 4 HBCUs nationwide. Majority of participants identified as Black or African American, 78% from Group 1 (henceforth referred to as Student Participants) and 51% from Group 2 (referred to as Faculty and Administrator Participants). Majority of participants also self-identified as male, 56% from Group 1 and 72% from Group 2. Additionally, most participants from Group 1 self-identified from various Engineering fields, such as the following: chemical engineering, mechanical engineering, computer engineering, and electrical engineering among others.

Primary barriers as indicated by the Student participants include the following: "Students lose confidence due to low grades in early STEM courses; Students have inadequate high school preparation in study skills; and Students are overwhelmed by the fast-paced STEM courses." The top barriers indicated by the Faculty and Administrator Participants include the following: "Students have inadequate high school preparation in study skills; Students have inadequate high school preparation in STEM subjects; and Students lose confidence due to low grades in early STEM courses." Comparing the findings of the two groups, it is remarkable that the top barriers for both groups share the same theme for 2 out of the 3 barriers. Further analyses indicated that gender differences for the Student Participants occurred on the following survey items: "Students have inadequate access to lab or lab facilities" and "Students think STEM career options are not worth effort to get degree." These findings will support the development and the structure of an operational model to address cultural intersectionality; institutional climate; and Engineering career trajectory in Engineering programs as HBCUs and nationally.

Introduction

The National Science Foundation (NSF) reported that approximately 80,000 Caucasian students enrolled full time for their first year in engineering programs across the United States (U.S.) compared to that of only 8,000 African-American students [1]. Such lack of representation of African-American students in engineering programs nationally supports the examination and supportive practices for improvement of Historically Black Colleges and Universities (HBCU) STEM programming for the graduation of engineering students and specifically Black or African-American engineering students. Literature also suggests that African-American students engage more with faculty at HBCUs [2]. According to Perna et al., as referenced by Hurtado et al., [2], HBCUs have supported Black students in the completion of about 30% of bachelor's degrees in the STEM fields. Such findings imply that students may persist in the completion of STEM degrees, such as engineering at HBCUs. Additionally, HBCU STEM programming and departments may be valuable research sites providing insight into student experiences, such as barriers or support experienced in their journey to complete STEM degrees.

To assist the nation in broadening participation and improve student success (i.e., persistence) in engineering, a group of research scholars conducted a research study focused on HBCUs. The researchers leading this effort are from different HBCUs across the nation and investigated individual factors, environmental factors, institutional practices, procedures, and policies that may adversely affect student success. To inform the present research study's efforts and development, the researchers comprehensively discussed areas of concern and observed trends, both nationally and at their respective institutions, to arrive at key research thrust areas for investigation: (1) cultural intersectionality, (2) institutional climate, and (3) Engineering career trajectory. Research across each of these areas will be guided by the theoretical framework for the college experience as developed by Terenzini and Reason [3]. This framework identifies specific factors affecting student persistence and participation in STEM as early as the first year of college. The goal of the present study is to present preliminary results of a survey to advance understanding of the educational experiences of STEM students and faculty at HBCUs. This study and its findings seek to enhance the persistence of STEM students, such as engineering students at HBCUs, foster engineering education research competence within HBCUs, and add to current literature and information regarding supportive practices for broadening participation and persistence of engineering students.

Methods

The researchers implemented an iterative, descriptive research model by including the following steps: (a) engaging research participants; (b) developing data collection strategies; (c) defining variables and constructs; and (d) gathering information and investigating research question(s). The present research study findings are informed by quantitative data analytics strand of the larger study.

Participants

Participants were recruited from four different HBCUs in the United States. Participants included the following: STEM Students; STEM Program Directors, Coordinators, and Staff; University Executive Administrators; STEM Academic College Deans; STEM Faculty; and STEM Mentors and Advisors. Each volunteer participant was eighteen years of age or older and was either enrolled or worked for one of the four participating HBCUs. For brevity and clarity

when referring to participants we will discuss the groups collectively as two separate groups. The two groups will be referred to as students (Group 1) and as leaders for faculty and administrators (Group 2).

Instrument Development

To investigate the perspectives of students and leaders, the researchers developed a questionnaire with a Likert scale (Rating: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree, 6 = Not Sure) for participants to rate their opinion of experiences in STEM majors at their HBCU. Survey items were developed to reflect the common reasons for student departure as outlined in the published text *Talking About Leaving* and the experiences of senior leaders on the project from STEM fields and at HBCUs [4]. To ensure the survey focused on the intended areas and that the researchers engaged in a comprehensive approach, each survey item was aligned with a research thrust area and compared with the theoretical framework. To account for differences in demographic information needed, two parallel surveys were created for each group (Group 1 and 2).

Data Collection

Data were collected from students (Group 1) and faculty (Group 2) from four HBCUs nationwide using surveys. The surveys were distributed online, in-person, or using both approaches. Hard copies were printed and disseminated to students in STEM major classes, student organization meetings, and at the university student center. Students were also emailed a link to the survey for online completion. These efforts resulted in a total of 648 participants across Group 1 (n = 579) and Group 2 (n = 69).

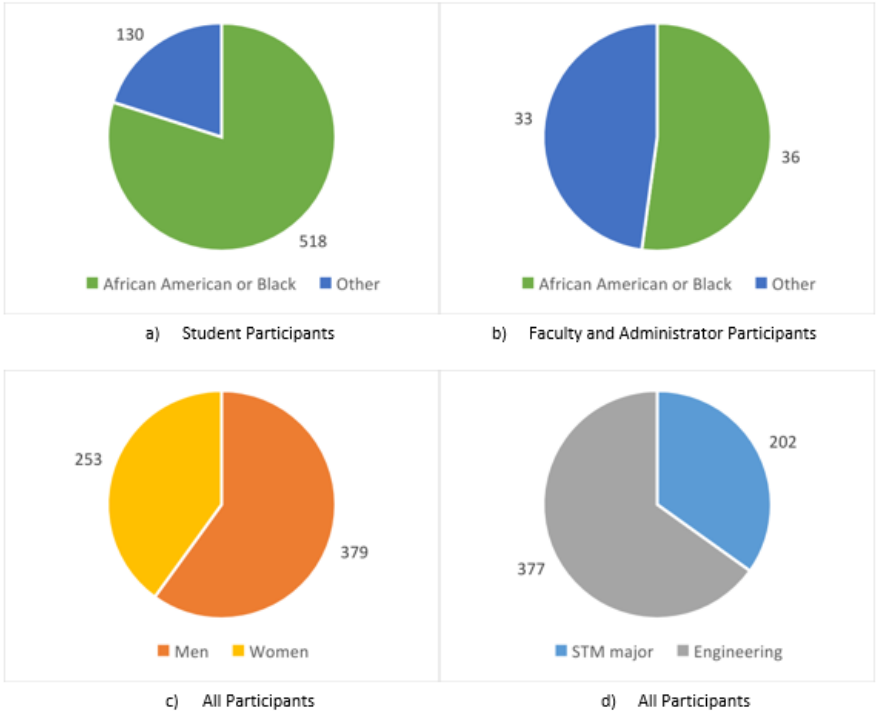

Figure 1. Demographic information of sample.

All student classification levels were represented in the survey results, from freshmen to graduate students. As can be seen from Figure 1, majority of participants self-identified as Black or African American in both groups with 80% in Group 1 and 52% in Group 2. Of those participants that self-identified their gender across both groups (n = 632), men comprised nearly 60% and women about 40% of the total sample. From Group 1, 202 students self-identified as a STM major (Science, Technology, or Mathematics) while majority of students, 377, self-identified as an Engineering major (including all concentrations).

Data Analysis

For preliminary data analysis, descriptive statistics—averages (i.e., means) and standard deviations—were derived using Microsoft Excel after initial data inputting, cleaning, and coding (where needed) were completed. Participant survey responses indicating a rating of 6 for "Not Sure" were omitted, as this was considered equivalent to a participant offering no response or no opinion.

Next, Kruskal-Wallis H test was conducted to identify group differences. The Kruskal-Wallis H test (sometimes also called the "one-way ANOVA on ranks") is a rank-based nonparametric test. In this instance, the researchers used a non-parametric test since the data was not normally distributed. Non-parametric tests, such as the Kruskal Wallis H test are often used to conclude if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable [5].

Results

Across the nation from four participating HBCUs, the data collected indicated consensus on 3 primary findings regarding STEM student persistence. These top 3 items, respectively based on means, are as follows: 1) "Students lose confidence due to low grades in early STEM courses; 2) Students have inadequate high school preparation study skills; 3) Students have inadequate high school preparation in STEM subjects." For Student Participants, the highest rated survey item resulting in a 4.07 mean response is the following: "Students have inadequate high school preparation study skills." For Faculty Participants, the highest rated survey item resulting in a 4.55 mean response is the following: "Students lose confidence due to low grades in early STEM courses."

Within each group, (i.e., for the student participants and the faculty and administrator participants) the researchers found statistically significant differences in responses to certain items on the survey.

Differences in Student Participant Responses Based on Gender

Across the 24 items on the survey, 4 items were found to be statistically significant responses from the student participants based on their gender: (1) Students lose confidence due to low grades in early STEM courses, (2) Students are overwhelmed by fast pace STEM courses, (3) Students have inadequate access to lab or lab facilities, and (4) Students think STEM career options are not worth effort to get degree.

Differences in Student Participant Responses Based on University

Across the 24 items on the survey, 7 items were found to be statistically significant responses from the student participants based on their university: (1) Students lose interest in STEM majors, (2) Students have inadequate high school preparation in study skills, (3) Students receive inadequate advising on academic problems, (4) Students are turned off by unforeseen length of

earning a STEM degree, (5) Students have inadequate access to lab or lab facilities, (6) Students encounter language difficulties with foreign faculty or TAs, and (7) Students think non STEM majors offer better opportunities.

Differences in Faculty and Administrator Participant Responses Based on Gender
Across the 24 items on the survey, the researchers found there to be no statistically significant response from the faculty and administrator participants based on their gender.

Differences in Faculty and Administrator Participant Responses Based on University
Across the 24 items on the survey, the researchers found there to be a statistically significant response from the faculty and administrator participants based on their university, for seven items: (1) Students lose confidence due to low grades in early STEM courses, (2) Students are overwhelmed by fast pace STEM courses, (3) Students think STEM career options are not worth effort to get degree, (4) Students shift to more appealing non STEM career options, and (5) Students reject STEM careers.

The statements along with the mean responses for both sets of participants and whether or not there were statistically significant responses for the statements based on gender and university of the participants are tabulated in the Figure 2 below. As mentioned earlier, the researchers used a non-parametric test: Kruskal Wallis H test. Laerd Statistics in their SPSS tutorial for the test remind users to recognize that the Kruskal-Wallis H test is an *omnibus* test statistic and cannot identify which specific groups of the independent variable are statistically significantly different from each other [5]. Thus, it only identifies if at least two groups were statistically significantly found to be different. This is a limitation of the dataset in that although the researchers are able to identify that statistically significant differences occur between the groups, the researchers are unable to identify which specific groups were different. To aid interpretation, mean responses are provided in the table below.

Statement	Mean Response for Faculty	Mean Response for Students	Statistically Significant Difference Based on University of Faculty	Statistically Significant Difference Based on the Identified Sex of Faculty	Statistically Significant Difference Based on Identified Sex of Student	Statistically Significant Difference Based on University of Student
Students lose interest in STEM majors	2.70	2.96	None	None	None	Statistically significant difference exists between the groups. P = 0.00
Students choose STEM majors for reasons that prove to be insufficient	3.18	2.94	None	None	None	None
Students lose			Statistically		Statistically	

confidence due to low grades in early STEM courses	**4.08**	**4.07**	significant difference exists between the groups. P = 0.00	None	significant difference exists between the groups. P = 0.02	None
Students have inadequate high school preparation in STEM subjects	**4.42**	**3.72**	None	None	None	None
Students have inadequate high school preparation in study skills	**4.55**	**3.82**	None	None	None	Statistically significant difference exists between the groups. P = 0.04
Students have inadequate family support	3.58	2.86	None	None	None	None
Students are overwhelmed by fast pace STEM courses	3.70	3.73	Statistically significant difference exists between the groups. P = 0.03	None	Statistically significant difference exists between the groups. P = 0.00	None
Students experience poor teaching by faculty or TAs	3.04	3.24	None	None	None	None
Students receive inadequate advising on academic problems	2.91	3.305	None	None	None	Statistically significant difference exists between the groups. P = 0.00
Students are turned off by unforeseen length of earning a STEM degree	2.62	3.21	None	None	None	Statistically significant difference exists between the groups. P < 0.0001

Students experience problems related to class size	2.4	2.71	None	None	None	None
Students have inadequate access to lab or lab facilities	2.38	2.58	None	None	Statistically significant difference exists between the groups. P = 0.02	Statistically significant difference exists between the groups. P = 0.00
Students encounter language difficulties with foreign faculty or TAs	2.87	3.35	None	None	None	Statistically significant difference exists between the groups. P < 0.0001
Students think non stem majors offer better opportunities	2.29	2.44	None	None	None	Statistically significant difference exists between the groups. P = 0.02
Students think non stem majors are more interesting	2.43	2.71	None	None	None	None
Students think stem career options are not worth effort to get degree	2.36	2.31	Statistically significant difference exists between the groups. P = 0.05	None	Statistically significant difference exists between the groups. P = 0.00	None
Students shift to more appealing non STEM career options	2.74	3.09	Statistically significant difference exists between the groups. P = 0.05	None	None	None
Students	2.31	2.61	Statistically	None	None	None

reject STEM careers			significant difference exists between the groups. P = 0.0084			
Student morale is undermined by competitive STEM cultures	2.70	3.11	None	None	None	None
Students lack peer support in STEM majors	2.87	2.76	None	None	None	None
Students are discouraged by unsupported faculty	2.71	2.99	None	None	None	None
Students experience prejudice and discrimination in STEM majors	2.52	2.49	None	None	None	None
Students do not gain a sense of belonging in their STEM majors	2.78	2.72	None	None	None	None

Figure 2. Results of analyses for each survey item across all participants groups**.**

Engineering Focus

The next round of analyses focused on a subset of the participants, comparing mean of the responses for those who had self-identified as majoring in Engineering or STM. In this analysis, the highest rated survey item based on means are as follows: "Students lose confidence due to low grades in early STEM courses." This is followed by survey items indicating that students have inadequate high school preparation in study skills and in STEM subjects.

Students		
Statement	**Engineering**	**STM**
Students lose confidence due to low grades in early STEM courses	**4.10**	**4.02**
Students have inadequate high school preparation in study skills	3.87	3.73
Students have inadequate	3.74	3.71

high school preparation in STEM subjects		

Figure 3. Engineering and Science, Technology, Mathematics Student group comparisons across means.

For faculty or administrators who identified as belonging to the Engineering department, the highest rated survey item based on means is as follows: "Students have inadequate high school preparation in study skills." This is followed by survey items indicating that students have inadequate high school preparation in STEM subjects and lose confidence due to low grades in early STEM courses.

Faculty or Administrators		
Statement	**Engineering**	**STM**
Students have inadequate high school preparation in study skills	**4.47**	**4.66**
Students have inadequate high school preparation in STEM subjects	4.32	4.55
Students lose confidence due to low grades in early STEM courses	3.94	4.27

Figure 4. Engineering and Science, Technology, Mathematics Faculty or Administrators group comparisons across means.

Discussion

Our preliminary findings support the results from literature discussing gender differences and high school academic training in STEM fields. For example, early learning of STEM subjects has been found to be a critical component of future learning of STEM topics [6]. Such findings support the notion suggested by the present study's findings, that high school training may support student persistence in engineering courses and degree completion at the university level. Further from the present study's findings, high school preparation of study skills may also influence experiences in STEM majors and courses at the university level. Grades at the university level in these STEM courses may also be linked to levels of confidence, which may affect student persistence in STEM majors.

Such findings across four HBCUs nationally and among students, faculty, and administrators convey the following suggestions for broadening participation and improving student persistence in STEM fields, such as engineering: preparation for STEM courses; and study skills development for STEM subjects. Efforts in preparation may prevent underperformance in STEM subjects at the university level, which may prevent loss of confidence and dropping out of STEM majors. Figure 5 depicts these connections in the form of a working model. Academic support, such as tutoring and instructional methods may reduce the likelihood of lower grades and students deferring from STEM majors at HBCUs.

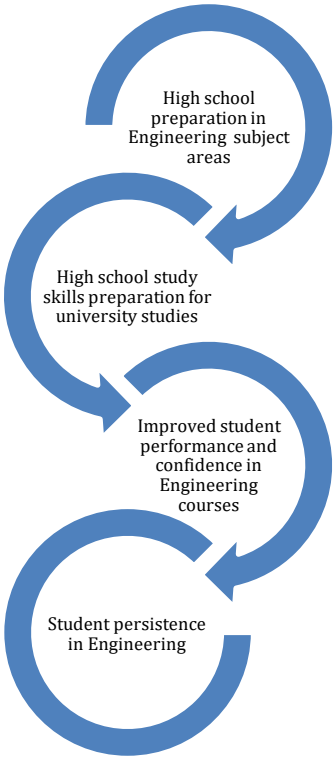

Figure 5. Working Model of Student Persistence for Engineering Career Trajectory.

Conclusion

Further research will advance an understanding of the overall experiences of STEM students at HBCUs and exposure to strategies that will broaden participation and improve student persistence in STEM fields, such as engineering. Further data is needed to address the research thrusts of cultural intersectionality and institutional climate. Experiences and factors, such as stereotypes and gender have been found to affect student preferences and learning in STEM subjects. Future suggestions and considerations for cultural intersectionality may include literature regarding stereotypes (experiences of race-based and gender-based stereotypes in STEM) and experiences of students based on gender as early as primary education [6], [7], [8]. Similarly, expanding on data collected to identify specificity in institutional experiences unique to HBCUs and engineering will support a greater understanding of this research thrust. The research thrust regarding Engineering career trajectory may be addressed considering factors of preparation to enter this area of study. Engineering career trajectory may be deferred if students are not persisting in the major as undergraduate students due to lack of preparation. Consideration of the current factors presented in the working model may support a positive Engineering career trajectory by implementing student preparation in STEM and in study skills upon entering university courses in engineering. It seems student preparation in STEM may lead to student persistence in these fields.

The researchers aim to conduct more in depth statistical analyses (e.g., multivariate data analyses), such as multiple regression analysis to further assess variables for predictability

purposes for persistence in STEM majors. The researchers also intend to continue data collection. Data collection from more HBCUs across the nation will provide a more comprehensive understanding of student experiences in STEM programs, such as engineering. The researchers plan to collaborate further with leaders across STEM departments to develop more data collection sites. Further research is warranted from these findings to assess links between high school preparation and STEM performance at the university level. Demographic information, such as first-generation college experiences would also be helpful data to assess student experiences regarding persistence. Gathering data regarding specific university courses that students experienced as difficult may identify areas needing further preparation for student persistence. Continuous data gathered nationally will be analyzed further to expand the development of strategic methods and more sophisticated models to address the two remaining research thrusts to effectively broaden participation and support student persistence in engineering.

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