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Undergraduate Progression: Tracking Undergraduate Students' Experiences To Elucidate the Critical Factors to Gaining STEM Identity within a STEM Scholars Program (SSP)

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Abstract

Over the past decade, reports such as the PCAST, National Research Council and AAAS' Vision and Change, have called for a shift to increase and diversify the number of minorities that participate in STEM programs and attain terminal degrees. Yet, there has been a stall in recruitment and retention of Black students that pursue and attain undergraduate degrees in STEM. Although HBCUs account for less than 3 percent of the universities and colleges in the United States, they produce 27 percent of Black students that earn bachelor's degrees in STEM. In this study, we highlight Black undergraduate STEM students that are participating within a structured STEM program. The program's mission is to increase the number of their students that engage in and choose to pursue terminal degrees or join the Department of Defense workforce as scientists and engineers.

Key Words

STEM Identity, Sense of Belonging, Persistence

Introduction

Over the past decade, reports such as the PCAST, National Research Council and AAAS' Vision and Change, have called for a shift to increase and diversify the number of minorities that participate in STEM programs and attain terminal degrees (AAAS, 2011; Briggs, 2017; NRC, 2003, PCAST 2012). Therefore, increased training of women and underrepresented minorities in STEM has been a national focus for diversifying the STEM workforce and meeting global demands (Boelter et al., 2015; Higher Education Research Institute, 2010).

Most STEM programs have been designed to provide opportunities for students to engage in hands-on research through project-based learning, CURES, or authentic research experiences, in

hopes of enticing and retaining them in STEM fields. Typically, after participation in these programs, studies are done that focus on lessons learned and student outcomes from the researchers' perspectives.

Bandura (1997) states, "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true" (p.2). Based on this premise, we wanted to understand students' perception of their current STEM program and their perceived contribution towards their STEM identity and career decision-making within a structured program.

The structured program has been designed and is currently being implemented by faculty and program directors who have earned their terminal degrees and use their knowledge and networks to expose students to different aspects of the experiences of practicing scientists and engineers. This design provides students with a greater insight in hopes of assisting them in gravitating towards becoming more central and less peripheral to the culture of engineers and scientists. Using a survey instrument, we assess STEM identity by tracking our students during their matriculation through an undergraduate program to determine the critical factors that contribute to their interest, perceptions, and career-making decisions as it pertains to the STEM disciplines. We anticipate that results from this study can contribute to the larger literature on the main variables within a STEM program that help cultivate and produce high achieving Black STEM scholars who attain their terminal degrees and enter the STEM workforce.

This paper highlights and analyzes constructs that lead to student satisfaction through participation in a structured HBCU STEM program (Hurtado et al., 2009). One of the program goals is to identify the critical factors that impact black undergraduate students' STEM identity. Understanding what influences their career decisions, their success academically, and the effects that these factors played on their confidence to persist was essential to this study. The paper is organized into the following sections. The background introduces the project framework. The next section provides an overview of the implementation of the program, followed by methodology and results. The last sections present challenges, future work and concluding thoughts.

Background

Sense of Belonging

STEM disciplines are lacking in diversity as it relates to having proper representation of minority students' performing research and pursuing STEM degrees and career opportunities (Hrabwoski, 2008; Syed, & Chemers, 2011). There are many programs targeted at increasing opportunities for underrepresented minorities in the scientific workforce and higher education (e.g., Meyerhoff Scholars Program, Maton et al., 2016; and the Biology Undergraduate Scholars Program at University of California, Jones, Barlow, & Villarejo, 2010). Research documents the lack of

diversity and reduced persistence can be attributed to the psychosocial factors of belonging and identity. This lack of diversity and representation can start to be addressed by students' feeling a sense of belonging during their exposures to STEM disciplines and practices (Leggett-Robinson et al., 2017). Additional studies show a sense of belonging plays a major role in developing identity and increasing persistence, especially for students of color (Byas-Winston et al., 2016). Lave and Wenger (2002) posit when students participate in STEM programs, whether as individuals or as a cohort, they need to have an atmosphere that they deem as supportive and will contribute towards their immediate and future goals. This idea was emphasized by Carolone and Johnson, 2007).

Self-Efficacy

The concept of self-efficacy has been determined as an influential construct in STEM education (Bandura, 1986; Nespor, 1987; Pajaras, 1992). Bandura posits self-efficacy as a judgement about one's ability to "organize and execute courses of action" to reach a certain goal (Bandura, 1981). In other words, it refers to an individual's belief that they can perform a task effectively and is predictive of performance level beyond predictions based on only objective measures of ability (Chemers et al., 2001). Science self-efficacy and career-making decisions (Lopatto, 2007) have been shown to be enhanced by authentic research experiences. Therefore, students from the current program of study had exposure to authentic research experiences in hopes of also contributing to their STEM identity.

STEM Identity

STEM identity is analyzed here based on Carlone and Johnson's (2007) theory of science identity. Science Identity is when the students recognize themselves as a scientist and it helps when others within the field they are interested in also recognize them as scientists. They identify three categories that define a strong science identity: 1) competence, 2) performance, and 3) recognition. When students are competent and are able to demonstrate science skills and knowledge, this aspect helps in creating their Science Identity, especially during social interactions (Carlone and Johnson, 2007). Individuals need to be competent or able to demonstrate skills and science knowledge. Studies that focus on student persistence and success often include STEM identity as one of the critical predictors for students continuing in STEM fields. When students, especially underrepresented minorities, do not feel or sense of belonging or have a STEM identity, this often results in withdrawal from academic pursuits or opportunities in the field and workforce (Hausman et al., 2007).

Mentorship

Previous studies have shown that during STEM engagement, such as internship or enrichment programs, the quality of student relationship with research or faculty mentors is a strong predictor of student satisfaction with the STEM engagement, even if the contact hours are low (Syed et al., 2018; Pfund, 2016).

These factors combined were investigated in this study in order to evaluate and bolster students' persistence, retention and intent to pursue graduate studies.

Program Description

The program of study is a five-year program designed for a cohort of Black undergraduate students with expressed interests in STEM, but have not solidified their majors. The selected students were high-achieving, Regional University merit scholars. The 17 student participants started the program during their pre-freshmen year. The program concludes one year after student participants graduate.

Program Information

The Regional University program is one that focuses on providing reinforcing scientific activities to bootstrap experiences for students while they navigate the journey of undergraduate studies to graduate school, professional school or the STEM workforce.

Seventeen pre-college merit students' scholars were selected to participate in our summer enrichment program led by their program directors who are three African American scientists (2 physicists and 1 molecular biologist, Regional University) one at their home institution and one external (Physicist at Regional University). Those students continued as freshmen during the academic year with pre-set curriculums for each major. Students were not allowed to deviate from the curriculum in order to guarantee four-year graduation rates. During the summer and continuing into the next three years, students participated in several STEM support activities designed to build a sense of identity and belonging within the cohort:

- Group science projects
- Weekly Research presentations
- Biweekly Journal Clubs
- Intrusive mentoring
- Mandatory enrollment in physics (first and second semester)
- Mandatory Friday Check-in (Students gathered weekly at the SSP Center to discuss and share with their classmates and program directors, their challenges, strategies and progress as they navigated the academic space)

These included students participating in group science projects with their program director mentors that included DNA barcoding, optics and optical matter, and applied computational sciences. The students did weekly research presentations and biweekly journal clubs in which they presented scientific articles or their summer research posters. Also for the sense of cohort and to build foundations for math and chemistry, all 17 students (physics and non-physics

majors) took physics for their first and second semester of their freshmen year. There was year round intrusive mentoring in which program directors met with the students mid-semester to discuss their current progress and their status academically, amongst their peers. The students also had to attend mandatory, weekly Friday meetings in which all students and the program directors meet to discuss strengths, challenges, and course-corrections as a group.

In order to assist students with interest-related research internships, during the first school year, DoD researchers and senior personnel visited the students in the Dean's Invited Guest Speaker Series. Students listened to the presentations and then asked questions about what the scientific workforce would be like at the DoD. During the second school year, students visited the DoD laboratories in Maryland and Washington, DC during a 2-day trip. They did speed-pairing rounds with different research scientists based on student research interests. They had the opportunity each to speak with at least 4 different scientists during one-on-ones. This was in preparation for the students to select internships in the summer. The students participated in summer internships, some after their freshman year physically, and most after their sophomore year, but this time it was virtually.

Realizing that the program was academically intensive and at times socially and mentally challenging, yearly psychological counselors visited our SSP center and did presentations and spoke with the students about coping mechanisms and resources available within their university.

Towards the end of their sophomore year, students were given resources to assist towards GRE and MCAT test preparation to continue to support their interests in the scientific and professional field preparation and to make them more competitive for their future goals.

After their virtual internships at the DoD-related labs, in order to assist students in beginning to feel like researchers, students presented their work during our virtual weekly meetings in preparation for conferences such as Annual Biomedical Research Conference for Minority Students (ABRCMS) and Advancing Minorities' Interest in Engineering (AIME) as a way of disseminating their research findings and to begin to work more central towards the practice and culture of being a scientists.

Methodology

Students participating in the program were asked to complete a survey during their junior year. The survey was designed to measure participant attitudes related to scientific self-efficacy, identity and belonging, and intention to pursue graduate studies in STEM, among other constructs, and was administered electronically. Additionally, students were asked in a retrospective format about research and academic gains made as a result of participating and any challenges they faced or additional supports they needed. The retrospective approach maximizes

ability to match responses and also eliminates pretest sensitivity and response shift bias, wherein students tend to underestimate or overestimate their attitudes towards the unknown prior to the start of an intervention (Howard 1980; Pratt, McGuigan, & Katzev 2000). Each of these constructs was measured using multiple representative items, and response items were given using a 5-point Likert scale of agreement (1=Strongly Disagree to 5=Strongly Agree). All student participants (N=13) responded.

Results

Overall, students reacted positively to their experience in the program and expressed satisfaction and excitement about the program. As a result of the program participation, 90% [*combined ratings of 4 and 5 on a 5-point Likert Scale*] of the participants indicated they have necessary tools for academic success, have a good working relationship with their mentors, and find research to be helpful toward STEM success. In particular, students gained a sense of identity and belongingness to the scientific community and engagement in their chosen academic and career path.

Table 1. Top factors for student program satisfaction

Constructs	**As a result of my program participation, ...**	**Mean**	**Assessment**	**% "strongly agree (5)"**
Mentorship	1. My mentors have been extremely helpful throughout my progression in the program.	4.69	Good	77%
STEM Engagement	2. I have all of the tools I need to be successful throughout undergrad, because of this program.	4.0	Good	31%
Research	3. The research I have done up until this point has been very useful to my future career.	4.08	Good	31%

Students were asked to consider their STEM identity prior to participation in the program and then to indicate their current STEM identity. Paired T-test comparisons were used to gauge the change in STEM identity perception overtime for each student. Data collected (Table 2) reveal that students showed a statistically significant increase ($p<0.05$) in STEM identity.

Table 2. STEM Identity & Belonging (Before/Now)

Construct: STEM Identity & Belonging	Before	Now	Paired Sample t-test
Mean	3.73	4.15	P = 0.0345*

Response averages for students "before" the program and "now". Scale= 1, Strongly Disagree to 5, Strongly Disagree. Assessment: Good = above 4.0; Attention = below 4.0; Action = below 3.5. **p<0.01, *p<0.05, ^p<0.10(approaching significance).

Qualitative data gathered through open-ended survey responses helped us to understand the impacts of program participation on their sense of belonging and further underscored their drive toward STEM success. Students enjoyed a **"sense of community**" experienced from participation in the program and reported **confidence, self-awareness, self-reflection, and self-direction** for their career path. These students expressed excitement about their career choice. The quotes below demonstrate the impact of "community":

> *Cohort has become very close*
>
> *Great to be a part of a group that is academically motivated*
>
> *Definitely enjoy the experience in STEM scholars program...with small tight group of students going through the same issues*

In addition, students valued regular interaction and positive feedback from mentors (program directors). These interactions allowed students to see themselves as future scientists; not surprisingly, this factor is an indicator of persistence. All Participants voiced that mentoring activities built confidence, motivated, and encouraged them to persist in the program and set career goals. Participants acknowledged the availability, transparency, and helpful nature of program directors as both academic and research mentors. The quotes below demonstrate the impact of mentorship; students were able to see themselves as scientists or engineers, and felt that they had a better understanding of where they were headed:

> *I never had a mentor before coming to Hampton University, but mentorship played a good role in giving me knowledge on where I want to go*
>
> *Feel like I can go to Dr. Ero-Tolliver and Lyons for anything; they have made my transition to school a lot easier*

Dr. Ero-Tolliver is a great mentor and really encourages her students to be the best version of themselves, because of how few Black PhDs are out there

Mentorship alleviates pressure; Great having them to talk to

Table 3. Demographic information of students participants

Participant	Gender	Academic Year	Major
Participant A	Female	Junior	Chemical Engineering
Participant B	Male	Junior	Biochemistry
Participant C	Female	Junior	Biochemistry (Spanish-Minor)
Participant D	Female	Junior	Mathematics
Participant E	Female	Junior	Electrical Engineering
Participant F	Female	Junior	Chemical Engineering
Participant G	Male	Junior	Physics
Participant H	Female	Junior	Electrical Engineering
Participant I	Male	Junior	Computer Science
Participant J	Female	Junior	Cellular Molecular Biology
Participant K	Male	Junior	Molecular Biology
Participant L	Female	Junior	Cellular Molecular Biology
Participant M	Female	Junior	Cellular Molecular Biology

There are currently 13 students in the program. All 17 original students did not remain in the program due to some not maintaining the 3.3GPA merit scholarship and program requirement.

Discussion

Recent data shows staggering statistics in diversity within STEM education. Women and minorities continue to be underrepresented in most STEM disciplines and occupations (NSF, 2015; Griffith, 2010). Different programs and studies are designed with the intent to boost minority involvement in STEM, but few investigate students' persistence towards sense of belonging, STEM identity and available resources within programs at HBCUs that cultivate minority student success in their STEM progression. This is of importance because the level to which students' perception of science identity and mentorship is usually what retains them in the STEM fields.

In this study, we have focused special efforts to document the students' reported level of science identity, sense of belonging and impact of mentorship (McGee, 2018) in setting their career goals. Our primary results show that mentorship, science identity, a strong sense of belonging, and consistent STEM engagement had positive effects on student persistence in STEM disciplines during the program. A growing body of literature shows that students who have had positive experiences in these variables are more likely to stay in the STEM fields and pursue them as viable careers. Finally students expressed that participation in research was useful towards their career-making decision. Research experiences can be internal or external to minority undergraduate students' universities. Although other factors influence STEM students' career decisions, authentic research experiences play a pivotal role for minority students' persistence and retention in STEM disciplines and careers.

Conclusions

In sum, our research shows that STEM identity, sense of belonging and mentorship are constructs that are valuable towards minority students' career-making decisions and persistence in STEM disciplines and programs. Our study also shows that having a sense of cohortness through different activities, that sometimes include taking central courses together, is highlighted as valuable to minority students' enjoyment and fulfilment within structured programs. If our goal as a society is truly to increase women and underrepresented minority participation in STEM, research into factors that cultivate and enhance STEM identity, such as a sense of belonging and self-efficacy of this population of diverse participants, will continue to be relevant. Especially, since we know these factors are important determinants towards graduate/professional schools and career-making decisions. Results from this work suggest structuring STEM programs to provide opportunities for students to gain STEM identity, self-efficacy, sense of belonging and proper mentorship in their development towards STEM careers.

Challenges

Some challenges/limitations of this study included student turnover and additional decision determinants. For example, although the students reported STEM identities, our data does not include all the descriptions of exactly how or when exactly they came to these realizations. Although the data includes information about students' rating of their STEM identity and more, our study does not contain our students' definition of STEM identity, sense of belonging or cohortness.

Due to the GPA requirement set by the program for students, the original seventeen students that began in the study were not all retained. Therefore, our student number participants changed from the original seventeen to now fourteen as shown in the survey. Although the reduction in student participants, we were still able to see statistical significance with some of our constructs. This change in student number mirrors some of the exiting of the minorities within STEM

disciplines that we typically see during their first and second year of undergraduate school. We continued to track the progress of students that left the program although they are no longer a part of this reported study. Some of the students that are no longer a part of the program are still STEM majors, but they are no longer financially supported by this program or through the university merit scholarships due to the GPA decrease below 3.3.

Due to the structured nature of this program, some aspects of this study may not be transferable to other institutions. Given the lack of students who identified as non-Black, it is important to state that our results may not transfer to non-represented populations.

Future Directions

Our future direction will focus on current program students' perception of their growing science identity, especially during different research experiences, to see if there is progressive change over time or if they maintain the same level of science identity post-graduation. In addition to these future directions, we plan to research student's perceived mediated impact of the role of race (Byas-Winston et al., 2019) and gender of their program directors and research mentors, if any, during the mentorship they received in the program on their persistence in STEM and career goals.

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