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Creating an Instrument to Measure Social and Cultural Self-efficacy Indicators for Persistence of HBCU Undergraduates in STEM

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Abstract

This study is part of a larger research that explores the creation of an instrument to capture the social and cultural factors that affect Black students' persistence in STEM. Most research on self-efficacy in the science education literature were either done at predominantly White institutions, during summer programs for students of color, or on predominantly White populations. This study provides insights into self-efficacy indicators at an institution that was specifically created to consider the social, cultural, and historical implications for educating Blacks in STEM. One hundred sixty-four undergraduate students enrolled in an introductory biology course at an Historically Black College and University completed a questionnaire. The survey addressed the hypothesized factors—expectancy, self-efficacy, familial self-efficacy, cognitive self-efficacy, and commitment. The results highlight the importance of science identity and familial sources of vicarious experiences as important indicators of persistence and performance in STEM. The importance of social and cultural factors for Black students' persistence in STEM is underscored.

Keywords Self-efficacy · HBCU · Vicarious experiences · Persistence · Blacks · STEM

This study is part of a larger research that uses pragmatism to explore the creation of a survey instrument. The goal of this instrument is to capture the social and cultural self-efficacy factors that impact Black students' persistence in STEM. Studies in science research programs often use self-efficacy as an indicator of persistence in science (Salto et al., 2014). However, research shows that when other factors, such as identity, are thrown into the mix, self-efficacy becomes a poor predictor of persistence in science (Estrada et al., 2011). This study capitalizes on the observations and experiences of faculty at an Historically Black College and University (HBCU) to explore factors related to utility value, expectancy, and cultural reproduction that might affect self-efficacy and persistence. This is done by drawing from the research literature in science education, social sciences, and

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applied psychology. This study adds to the literature with students at predominantly Black institutions as a study population. Most studies in self-efficacy, that include students of color, were either done at predominantly White institutions (PWI) or with students of color enrolled in summer research programs.

While HBCUs make up only 2% of all degree-granting institutions in the USA, HBCUs are the second largest producer of all Black doctorates in Science and Engineering (NSF, 2018). Furthermore, 24% of Blacks with doctorates have bachelors from HBCUs (NSF, 2018). HBCUs are the only higher education institutions that were originally created to advance the academic performance of Blacks. HBCUs are unique in ensuring that students are historically, socially, linguistically, and culturally aware, with the goal to advance and address the academic achievements of the African Diaspora. The African Diaspora refers to all Black people of African heritage who were brought out of Africa through the slave trade to the different parts of the world.

Science education research on identity and self-efficacy reflects a small number of Blacks in predominantly White higher education institutions, if Blacks are present at all. Walls (2016) concluded from his research review on the nature of science that the experiences of Blacks are unique enough to warrant separate study. Walls found that the experiences of Blacks are not reflected in "nature of science" studies done in prominent science education journals. This study safely assumes that this is also the case for research that looks at the impact of research programs on self-efficacy, as research programs are predominantly used to study impacts of nature of science understandings. The literature review that follows uses pragmatism to explain how the research literature was used for a more integrated instrument.

Literature Review

Bandura's Self-Efficacy Framework

Science education research on the impact of self-efficacy on student performance in STEM use Bandura's (1997) self-efficacy theory which addresses the complex nature of "perceived self-efficacy as a generative capability" (p. 36). Bandura indicates that the development of self-efficacy or individual agency is influenced by recognition that certain actions produce certain outcomes, the differentiation of oneself from others, familial sources, the development of self-appraised skills, the impact of childhood adversities, peers, school, transitional experiences in adolescence, adulthood experiences such as occupational roles, family roles, cognitive changes, and socio-structural constraints to name a few. Thus, this research uses Bandura's (1997) descriptions of the main sources of self-efficacy—(1) enactive mastery experience; (2) vicarious experience; (3) verbal persuasion; and (4) psychological and affective states—to explore and explain the research findings in science education and other related fields, by highlighting the connections between the social, cultural, and historical relationship between language, learning, and society (Enciso & Ryan, 2011) and the plights of Blacks in STEM.

Enactive Mastery Experience

According to Bandura (1997), enactive mastery is the most important source of self-efficacy. Enactive mastery provides students with the opportunity to experience success and failures, to learn to overcome failures, and to develop the agency to enact specific experiences. Students could then view failures as opportunities to learn and pursue challenges. Enactive mastery is influenced by pre-existing self-knowledge structures, task difficulty, and contextual factors to name a few (Bandura, 1997). The enactive mastery experiences for Black students have been very different from those of White students (Boykin & Noguera, 2011; Walls, 2016). Unlike White students, the mastery experiences of Black students do not promote scientific research experiences that help them understand the nature of science (Walls, 2016).

Thus, summer research programs in STEM were specifically designed to provide students of color with these experiences, which lead to increased self-efficacy in STEM (Salto et al., 2014). However, research shows that even when Black students display high self-efficacy because of their enactive experiences, the connection between self-efficacy and identity as a scientist do not correlate for African Americans, Latino, or Native Americans (19%) as it does for Asian American or European American (46%) (Robnett et al., 2015). Robnett et al. (2015) concluded that some other factors were at play but did not identify what these factors were.

Wong et al. (2019) found that academic hardiness and motivation in middle school Malaysian students correlated with self-directed learning and collaboration. Cheung (2015) found that self-efficacy levels were higher in high school Hong Kong students who were given the opportunity to learn from classmates in friendly environments. However, Boykin and Noguera (2011) show that Black students were more often left to work in isolation than in groups compared with White students. Margolis et al. (2000) found that undergraduate females in computer science often worked in isolation which lead them to attribute their struggles to a bad fit rather than to unsupportive institutional structures.

The development of mastery skills for Blacks is especially challenging because their science learning does not make use of their language or prior experiences. Brown (2004, 2006) found that ethnic minority high school students experienced conflicts and challenges in appropriating the language of science even when they attempted to make sense of science concepts. Moore (2007) describes language as the gatekeeper of discourse and power that can alienate women and minorities and advocates for an understanding of scientific discourse in order to empower students. Enciso and Ryan (2011) note that "the potential to learn is optimal within situations where a problem makes use of and extends the language, knowledge, motivation and relationships already available to learners" (p. 133). Warren et al. (2001) found that if encouraged diverse students can effectively use their everyday language during sense-making in science. Science requires engagement in scientific discourse. Thus, it is important that the role of language and discourse is addressed in self-efficacy studies, especially for Blacks.

Vicarious Experiences

Vicarious experiences provide individuals with access to different kinds of modeling. Modeling can convey coping strategies and be diagnostic of one's capabilities. The impact of modeling can depend on the amount of uncertainty or direct knowledge an individual has about one's own capabilities. Modeling can come in many forms and may be aspirational or psychological depending on one's available networks or symbolic such as that provided by television or other media (Bandura, 1997).

The impact of symbolic modeling is captured in Wong's (2015) study on "Careers 'from' but not 'in' science: Why aspirations to be a scientist are challenging for minority ethic students?" as their study was titled. Wong found that for 46 British students age 11 to 14 their science identity was inextricably linked to their ethnicity and to the belief that they might be venturing into unchartered territory. They perceived scientists as typically "White male" and science as a male-dominated field. Moreover, careers in science such as becoming a veterinarian were seen to offer financial security unlike being a scientist. The importance of symbolic modeling also plays out in Walls (2012) findings that African American third grade students' views of scientists conformed to the stereotype of White males in lab coats even when students were not shown stereotypic images in the study.

Blacks have fewer modeled attainments as is supported by the low numbers of Blacks in science. Research programs have included a mentoring component to give students of color an opportunity to learn from vicarious experiences. Syed et al. (2012) examined the relationship in preferences for mentors of matched background and the amount of contact with mentors that high achieving diverse students received during a 4-week summer science program. They found that while there were overall individual differences in preferences for students of color, they were most often in the "no contact" or "low contact" clusters even with increasing access to mentors. Alternatively, White students were mostly in the no preference and high contact groups, where they remained throughout the program. Syed et al. found that students of color who initially display high preferences for matched mentoring reported experiencing more mentoring and an increasing sense of belonging and identity as a science student. They concluded that these feelings of belonging and identity as a science student was "an essential component of committing to a career in science" (Syed et al., 2012, p. 906).

Peers provide one source of vicarious experiences. Webb-Williams (2018) found that in a study of 84 girls and 98 boys aged 7 and 12 years old from two public junior schools in the UK, girls were more likely to make judgements about their own performance using social comparisons with other girls. Their findings are supported by their observation that "feelings or emotional reactions" surrounding these judgements were more frequent for girls. Sources of self-efficacy included mastery experience, social persuasion, vicarious experience, physiological/affective states, and self-regulation. The frequency of vicarious experience was 71% for girls and 29% for boys, and the proportion of vicarious experiences compared to all sources was 41% for girls and 19% for boys.

Verbal Persuasion

According to Bandura (1997), verbal persuasion may contribute to or undermine perceived self-efficacy. Verbal persuasion may take the form of expressions of "faith in one's capabilities" (p. 101) by close family members, teachers, or friends. They may be in the form of feedback, which affects the amount of effort put into a task, or social evaluations which "are often conveyed indirectly or subtly toward people believed to be of limited aptitude" (p. 102).

The research literature is rampant with examples which show that the verbal persuasion experiences of Black students are very different and very negative compared with White students. Brown et al. (2016) found that African American scientists and science majors experienced microaggressions, which are subtle forms of racism: "People say things to me that are racist because I am a (Black scientist/science major)" (p. 157). According to one African American scientist, "My views often need backing by a senior scientist" (p. 260). Brown et al.'s (2016) study highlights the importance of context and assumptions for how African American scientists and science majors align themselves with their communities, and the strategies they possess or develop for aligning with various communities: "As a graduate student working at the NIH, I did not feel that people saw me as a young scientist. However, at Howard University I was comfortable in my community and viewed as a scientist" (Brown et al., 2016, p. 160). The importance of context means that the results of surveys on self-efficacy and identity in Blacks might show variations when explored at an HBCU as opposed to a predominantly White institution (PWI).

Mutegi's (2013) science education article titled "'Life's first need is for us to be realistic' and other reasons for examining the sociocultural construction of race in the science performance of African American students," begins with an example that highlights the impact of negative verbal persuasion from a teacher who succumbs to assumptions about African Americans. Even though this teacher believed that the student was capable, his low expectations and stereotypic assumptions led him to suggest "Malcolm, one of life's first needs is for us to be realistic... You need to think about something you *can* be" (p. 83). These verbal persuasions are commonplace for Blacks where teachers are motivated by the individual and the context of a racial society, rather than empowered to help students develop their own assets. When it comes to studying females' choices in science subjects and the role of peers, Panizzon and Levins (1997) suggest a more holistic and generalized approach that includes the "individual's ethos and culture" (p. 265). Thus, context is expected to influence the motivated thinking, outcomes, and selected preferences in the survey.

Physiological and Affective States

Bandura (1997) describes the complexity of understanding the impact of physiological and affective states on one's self-efficacy. The factors that influence one's physiological states may include but is not limited to pre-existing self-efficacy, physiological and affective states, and environmental factors which influences one's internal state and how one interprets a situation or one's own internal state.

Physiological and affective states could explain the lack of correlation between self-efficacy and science identity for African American, Native American, and Latinx students in Robnett et al.'s (2015) study. Estrada et al. (2011) found that when they re-examined studies that showed that self-efficacy was an indicator of minority students' intention to pursue science careers, they found that self-efficacy was no longer an accurate predictor when other factors were controlled. Identity as a scientist and value attached to science were better predictors of the degree to which students were integrated into the scientific community.

Gee (2000) describes four ways of viewing identity—nature identity, institutional identity, discourse identity, and affinity identity. These four positions are defined by the extent to which identity is perceived as "natural" or defined by "nature," or the extent to which they are viewed as defined by individual experiences. Gee (2000) explains that these categories are fluid because as individuals we move through these positions depending on where we are in our lives. This is supported by Bandura's synthesis of physiological and affective states:

> In the sociocognitive view (Bandura, 1986a), knowledge about bodily states is acquired, in large part, through social labeling coordinated with experienced events. Arousing experiences contain three significant events, one of which remains private

> and two of which are publicly observable. These include environmental elicitors, expressive reactions, and social labeling (Bandura, 1997, p. 107).

Thus, a Black undergraduate student's response to a question on whether they look forward to working in a lab depends on attributes of the lab given attention to or the social experiences or collective views activated.

Let's imagine for a moment that all Black students are familiar with the lack of recognition Blacks, particularly Black women, receive in labs, and the need to fight for recognition as described in Carlone and Johnson's (2007) study. As supported by Bandura (1997), an individual with high self-efficacy might view this as a challenge rather than a deterrence. Survey selection indicating they look forward to being in a lab can be construed either as a focus on the prize or a readiness for challenge, or possibly though less likely, total oblivion to the plight of Blacks. Molden and Higgins (2005) indicate that motivated thinking can be characterized as either "outcome motivated thinking" or "strategy motivated thinking" and that outcome motivated thinking consists of directional outcomes and nondirectional outcomes. If we apply these ideas to outcomes in an efficacy questionnaire, one thought suggests that students whose thinking is motivated by directional outcomes would be most interested in their final impressions of themselves or people close to them, "as intelligent, caring, and worthy" (Molden & Higgins, 2005, p. 296). An individual with nondirectional motivation is motivated by accuracy (Molden & Higgins, 2005); this could assume the need for accurate perception of one's self-efficacy or one's place in the scientific community. Thus, results from questions that gauge this expectancy could be the result of either a perceived accuracy motivation about oneself or closure motivation that leads one to consider, "Life's first need is for us to be realistic" (Mutegi, 2013).

Other factors are implicit in one's physiological affective states. These include the levels of activation of various cognitive and physiological states, pre-existing beliefs, mood as determined by the congruency of learning environments with performance environments, and how all of these factors integrate. Dumbauld et al. (2014) explored the importance of mentorship and self-efficacy as a social and cultural factor that affects learning in medical students. Dumbauld et al. (2014) looked at the Index of Learning Styles (ILS) as an indicator of self-efficacy and found that changes in learning styles and the nature of learning styles were a much better indicator of increased self-efficacy than their initial baseline self-efficacy scores. Thus, students' willingness to make changes and invest in the learning process can be an indicator of the value they attach to learning STEM. The ability to regulate one's learning may also indicate self-efficacy and self-empowerment in STEM.

Contribution to Science Education

Studies on self-efficacy in STEM have looked at the influence of developing mastery skills, such as research skills, on self-efficacy. Likewise, studies on identity as a scientist attach identity as a scientist to feelings of self-efficacy in STEM performance. However, these studies have not considered the impact of social, cultural, and historical underpinnings on collective efficacy or the implications of collective efficacy on individual efficacy. This study therefore considers the impact of related cultural and cognitive factors on self-efficacy. Thus, the uniqueness of this study with HBCU students is in considering the multifactorial influences on motivation. More importantly, this study takes the perspective that the social, cultural, historical, political, linguistic, and educational underpinnings are critical considerations or influencers on Black students' motivation to pursue mastery in STEM areas.

Methodology

Participants and Setting

Participants were undergraduates from an HBCU. Students were enrolled in an introductory biology course. A total of 164 students completed 100% of the survey which included 116 (0.71) first year students, 42 (0.26) sophomores, 4 (0.02) juniors, and 2 (0.01) seniors. One hundred forty-two (0.87) were females, 1 (0.006) was gender non-conforming, and 21 (0.13) were males. Students identified ethnically and culturally as African American 127 (0.77), African 12 (0.073), Afro-Caribbean 16 (0.09), and other 17 (0.10). Eight of the 17 students in the "other" category described themselves as Afro-Latino (1), Asian (3), White (1), multi-racial (1), biracial (1), Asian/African American (1), and African American/Creole/Kittitian Nevisian (1). Overall, 100 (0.61) selected Biology as their major; Health Sciences 24 (0.15); Nursing 1 (0.006); other STEM 13 (0.08); and other 26 (0.16) were the other majors selected. Ninety-nine (0.60) were not enrolled in any funded research or special lab programs; 61 (0.37) were in a research-intensive lab section; 2 (0.012) were involved in a minority research program; and 2 (0.012) selected other research projects. Institutional IRB approval was obtained prior to data collection for this study. Students who agreed to participate signed the consent form and completed the questionnaire through Qualtrics.

Procedures and Measures

The authors are researchers and professors at an HBCU in the fields of science education and qualitative research (first author), educational psychology and statistics (second author), and biology (third author). The first author designed the instrument. Construct and content validity was informed by the science education and other research literature and informal discussions/feedback between STEM faculty and first author.

The factors explored in this paper were (1) expectancy or motivated thinking; (2) self-efficacy; and (3) familial self-efficacy; (4) cognitive self-efficacy; (5) commitment; and (6) science identity which used a 5 point Likert scale that ranged from 1 (strongly disagree) to 5 (strongly agree).

Operational Definition of Hypothesized Factors

Expectancy

Expectancy referred to students' motivated thinking about their future in science. Students were asked three questions: Becoming a scientist would be very useful to me in the future; I see myself becoming a scientist; I look forward to working in a science lab. A high score on these questions means that students' expectancy is unhampered by the dominant perspective such as scientists are typically White male or by narratives or possible experiences or projected fears of hostility in future interactions, as some HBCU students have felt while working in internships in predominantly White institutions (a study for another day). This could also inform on the nature of intrinsic (score of 5) or extrinsic (score of 1) motivation to becoming a scientist.

Self-efficacy

In keeping with Bandura's definition of self-efficacy, this factor measures students' beliefs about their own ability to succeed in science, their feelings about their own mastery, and their vicarious experiences. Three questions were asked: I am a successful science student; I am confident about my ability to do well on my own during lab activities and lab explorations; I doubt my own ability to do well in science when others have difficulty. A high score means that students have high beliefs or high individual self-efficacy about their own capability to perform well in lab experiences and in science in spite of others.

Familial Self-efficacy

This factor measures the exposure to vicarious experiences that could have influenced the student. Questions asked were: I am close to someone who is in STEM; One of my close relatives is a scientist; and One of my close relatives works in a STEM field. Thus, rather than ask students if one of their relatives is in STEM, the use of the word "close" could indicate opportunity for interactions. A high score or high familial self-efficacy indicates that these affiliations might have an effect which might or might not be positive.

Cognitive Self-efficacy

If students are willing to alter their behavior to succeed in science, it means that they are empowered to do so or exhibit adaptive behavior that could carry over to success as a scientist. Questions included the following: I work hard to understand science. I have changed how to go about learning in order to do well in science. I am willing to change the way to go about learning in order to do well in science. A high score could also indicate self-awareness and empowerment, as well as high cognition for science especially if students indicate that they have already made adjustments in their learning.

Commitment

Feelings of commitment indicate students' anticipation or anticipated short-term or long-term goals to pursue STEM. Three questions asked include the following: I look forward to working with people in STEM; I plan to pursue a doctoral degree after I am done with my undergraduate degree; I plan to continue into an advanced degree immediately after graduating with my STEM degree. A high score indicates students' commitment and their understanding of the long-term learning investment in becoming a scientist and that is required by the STEM field.

Science Identity

Science identity indicates the extent to which students identify or associate with being a scientist. Questions asked included: I am a scientist; I am familiar with scientists in my local community; and Scientists use the same everyday language that I do. A high score means that students feel comfortable identifying themselves as a scientist and/or they feel that being a scientist defines who they are.

Exploratory Factor Analysis

An exploratory factor analysis (EFA) using principal axis factoring with oblique rotation was conducted. Principal axis factoring (PAF) was used instead of principal components analysis (PCA) because the latter is a data reduction technique that does not discriminate between unique and shared variance—and as a result, latent factors are not the focus of the analysis (Henson & Roberts, 2006). PAF was also used because it is less likely than PCA to inflate estimates of variance accounted for by the given factors (Henson & Roberts, 2006). Also, the use of oblique rotation is recommended if correlations between factors are expected (Pett et al., 2003), as was the case with factors in this instrument.

Four different procedures were used to determine the factor structure: eigenvalues greater than one, scree plot, parallel analysis (PA), and the minimum average partial (MAP) test. PA and the MAP tests are not only the more accurate methods of factor extraction but also complementary to each other: in the worst-case scenario, parallel analysis tends to overextract while the MAP test tends to do just the opposite (Hayton et al., 2004). Hence, the use of both methods in guiding decisions about factor extraction reduces the risk of over or under extraction.

Results

Based on the factor-selection criteria mentioned previously, a seven-factor solution was most viable. The Kaiser criterion (i.e., eigenvalues above one) suggested the extraction of seven factors, as did the scree plot (see Fig. 1), the MAP test, and parallel analysis. Jointly, these factors explained 67.6% of the variance in all the items on the scale.

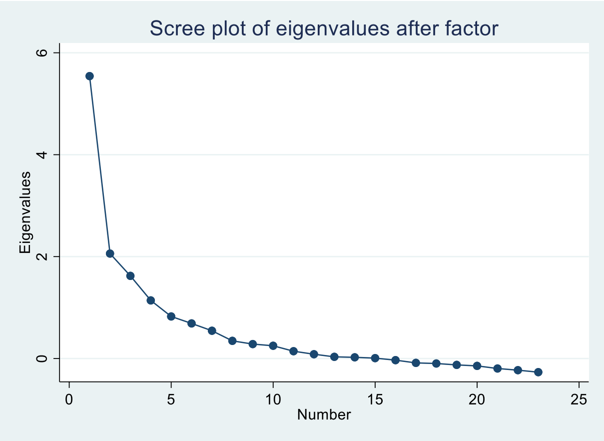

Fig. 1 Scree plot 7-factor solution

Seven-Factor Solution

Factors 1–7 (expectancy, cognitive self-efficacy, familial self-efficacy, self-efficacy, commitment, science identity, mixed) explained 25.82%, 11%, 8.69%, 6.92%, 5.64%, 5.12%, and 4.44%, respectively, of the total variance in the items.

Pattern and structure matrices generated from the EFA were analyzed to evaluate the quality of the items, specifically with regard to uni-dimensionality. The pattern matrix is a matrix of standardized coefficients that reflect the relationship between the items and the latent construct that they are purported to measure. Specifically, these coefficients, called factor loadings, indicate the effect of a given factor on a given item while controlling for other factors. The pattern matrix assesses whether the items are measured only by the given factor to which they are hypothesized to belong, and no other. High factor loadings indicate strong relationships between the item and its factor. Factor loadings between 0.45 and 0.54 are considered fair, and loadings above 0.55 are good (Comrey & Lee, 1992). Hence, quality items are marked by high communalities, high factor loadings on their hypothesized factors, and very low to no cross loadings on other factors (i.e., uni-dimensionality).

A close examination of the factors in the pattern matrix shown in Table 1 revealed evidence of multi-dimensionality among factors, discussed in detail below. Although the factor analysis yielded factors that denoted the above six factors, an extra factor emerged that contained three items, which did not load on the factor to which it was originally assigned (cognitive self-efficacy (s49)). The remaining two items (v29 & 30) were multidimensional, cross loading with moderate to high factor loadings on this, and the original factor to which they were assigned (cognitive self-efficacy). Additionally, two items assessing identity (d20) and commitment (p44) loaded on the wrong factor (expectancy). One item had very low factor loadings with its factor (less than 0.33). Items that performed poorly were removed systematically. First, the three items that loaded on the wrong factor were removed, and a factor analysis was re-run.

The Revised Model

The second exploratory factor analysis yielded a six-factor solution that corresponded with our hypothesized factor structure.

Communalities

Overall, communalities—the variance in each item explained by its factor—were moderate to high (Fabrigar et al., 1999) ranging from 0.31–0.85.

Pattern and Structure Matrices

As seen in Tables 2, 3, and 4, the pattern and structure matrices had high factor loadings, and all items loaded on their respective factors only, indicating that uni-dimensionality had been achieved. Item-factor loadings on the pattern matrix were moderate to strong and ranged from 0.33–0.92 for the six factors. The moderate to strong range of values for these items relative to their factors suggests a strong relationship between the items and their respective factors after controlling for other un-related factors and variables. Similarly, the structure matrix shown in Table 2 revealed moderate to strong item-factor loadings for all factors, ranging from 0.38–0.88, indicating moderate to strong correlations between items

Table 1 Pattern matrix for the seven-factor solution

	Expectancy	Cognitive self-efficacy	Familial self-efficacy	Self-efficacy	Commitment	Science identity	Mixed
D21 I see myself becoming a scientist	.841						
V23 Becoming a scientist would be very useful to me in the future	.805						
P48 I look forward to working in a science lab	.499						
P47 I would like to begin to work in a STEM field immediately after graduation with my STEM degree	.330						
V29 I work hard to understand science							− .729
V30 I have changed how I go about learning in order to do well in science		.378					− .562
V31 I am willing to change the way to go about learning in order to do well in science		.656					
S49 I know I can do well when I see people like me able to do something challenging		.591					
C40 I am close to someone who is in STEM			.577				
C41 One of my close relatives is a scientist			.720				
C42 One of my close relatives works in a STEM field			.921				
S10 I am a successful science student				.671			
S11 I am confident about my ability to do well on my own during lab activities and lab explorations				.809			
S12 I doubt my own ability to do well in science when others have difficulty				.634			
S28 I am a good researcher in science				.374			
P27 I look forward to working with people in STEM					− .405		
P37 I plan to pursue a Doctoral degree after I am done with my undergraduate degree					− .563		
P50 I plan to continue into an advanced degree immediately after graduating with my STEM degree					− .731		
P44 I want to take a break from studying science after graduating with my STEM degree	-.381				.430		
C18 I am familiar with scientists in my local community						.556	

Table 1 (continued)

	Expectancy	Cognitive self-efficacy	Familial self-efficacy	Self-efficacy	Commitment	Science identity	Mixed
D19 I am a scientist						.551	
D20 I see myself as a scientist	.356					.519	
D22 Scientists use the same everyday language that I do						.496	

Table 2 Communalities for the seven-factor solution

	Initial
S10 I am a successful science student	.525
S11 I am confident about my ability to do well on my own during lab activities and lab explorations	.545
S12 I doubt my own ability to do well in science when others have difficulty	.375
D19 I am a scientist	.481
C18 I am familiar with scientists in my local community	.249
D21 I see myself becoming a scientist	.725
D22 Scientists use the same everyday language that I do	.308
V23 Becoming a scientist would be very useful to me in the future	.662
P27 I look forward to working with people in STEM	.386
V29 I work hard to understand science	.372
V30 I have changed how I go about learning in order to do well in science	.442
V31 I am willing to change the way to go about learning in order to do well in science	.370
P37 I plan to pursue a Doctoral degree after I am done with my undergraduate degree	.320
C40 I am close to someone who is in STEM	.388
C41 One of my close relatives is a scientist	.524
C42 One of my close relatives works in a STEM field	.577
P47 I would like to begin to work in a STEM field immediately after graduation with my STEM degree	.353
P48 I look forward to working in a science lab	.525
P50 I plan to continue into an advanced degree immediately after graduating with my STEM degree	.432

Extraction method: principal axis factoring

and their respective factors. There was not that much difference between the pattern and structure matrix with respect to the item-factor loadings, which suggests low correlations between the factors.

Factor Correlations

Table 5 shows factor correlations between the six factors in our scale. Expectancy and familial self-efficacy were positively correlated with each other, indicating that more exposure to vicarious experiences in STEM was related to motivated thinking about a future in science. Moreover, both these factors were negatively correlated to all the other factors in the scale, except for science identity. Thus, familial self-efficacy and science identity are important motivators in expectancy. In broad strokes, this could mean that students might view being a scientist as useful because they observed the usefulness of being a scientist. Alternatively, if being a scientist is part of the everyday language they use and they have pleasant associations with STEM, then it might be easier to see themselves as a scientist. Here, expectancy or highly motivated thinking about a future in science is associated with a stronger science identity. That expectancy does not correlate with self-efficacy, cognitive self-efficacy, and commitment to STEM could mean that other factors are at play, for example, given this sample of students, cognitive efficacy in science might be more related to the importance of their overall academic performance than a pursuit of STEM. They might perform well in science but still do not see being a scientist as useful. Alternatively, one's identity could be central to one's persistence in STEM. Higher levels of familial self-efficacy were linked to lower self-efficacy, cognitive

Table 3 Pattern matrix for the six-factor solution

	Expectancy	Familial self-efficacy	Cognitive self-efficacy	Self-efficacy	Commitment	Science identity
D21 I see myself becoming a scientist	.797					
V23 Becoming a scientist would be very useful to me in the future	.937					
P48 I look forward to working in a science lab	.467					
I would like to begin to work in a STEM field immediately after graduation with my STEM degree						
C40 I am close to someone who is in STEM		.570				
C41 One of my close relatives is a scientist		.717				
C42 One of my close relatives works in a STEM field		.903				
V29 I work hard to understand science			− .516			
V30 I have changed how I go about learning in order to do well in science			− .895			
V31 I am willing to change the way to go about learning in order to do well in science			− .447			
S10 I am a successful science student				− .686		
S11 I am confident about my ability to do well on my own during lab activities and lab explorations				− .748		
S12 I doubt my own ability to do well in science when others have difficulty				− .646		
P27 I look forward to working with people in STEM					− .450	
P37 I plan to pursue a Doctoral degree after I am done with my undergraduate degree					− .589	
P50 I plan to continue into an advanced degree immediately after graduating with my STEM degree					− .761	
C18 I am familiar with scientists in my local community						.593
D19 I am a scientist						.376
D22 Scientists use the same everyday language that I do						.571

Table 4 Structure matrix for the six-factor solution

	Expectancy	Familial self-efficacy	Cognitive self-efficacy	Self-efficacy	Commitment	Science identity
D21 I see myself becoming a scientist	.848			− .418		.414
V23 Becoming a scientist would be very useful to me in the future	.872					
P48 I look forward to working in a science lab	.632		− .404			.433
I would like to begin to work in a STEM field immediately after graduation with my STEM degree	.416				− .379	
C40 I am close to someone who is in STEM		.608				
C41 One of my close relatives is a scientist		.726				
C42 One of my close relatives works in a STEM field		.878				
V29 I work hard to understand science			− .549			
V30 I have changed how I go about learning in order to do well in science			− .872			
V31 I am willing to change the way to go about learning in order to do well in science			− .514		− .371	
S10 I am a successful science student		.333		− .729		
S11 I am confident about my ability to do well on my own during lab activities and lab explorations				− .788		
S12 I doubt my own ability to do well in science when others have difficulty				− .634		
P27 I look forward to working with people in STEM	.401		− .364		− .571	
P37 I plan to pursue a Doctoral degree after I am done with my undergraduate degree					− .566	
C18 I am familiar with scientists in my local community						.570
D19 I am a scientist	.501			− .467		.545
D22 Scientists use the same everyday language that I do						.601

Table 5 Factor correlation matrix

Factor	Expectancy	Familial self-efficacy	Cognitive self-efficacy	Self-efficacy	Commitment	Science identity
Expectancy	—					
Familial self-efficacy	.135	—				
Cognitive self-efficacy	− .279	− .260	—			
Self-efficacy	− .240	− .174	.141	—		
Commitment	− .356	− .174	.346	.119	—	
Science identity	.364	.118	− .041	− .227	− .076	—

self-efficacy, and long-term goal commitment to STEM. Thus, self-efficacy, cognitive self-efficacy, and long-term commitment might not be tied to familial self-efficacy if closeness to family paints a bleak picture of STEM. This is especially true if the family member who is a Black scientist has negative experiences in the field or face challenges to success. This is also consistent with the low numbers of known Black scientists as well as research on the negative experiences of blacks in science. Nevertheless, the low correlations between the factors as shown in the factor correlation matrix above are indicative of discriminant validity.

Reliability Analysis

Reliability analysis was conducted in Stata 15. Corrected item-total correlations, squared multiple correlations, average inter-item correlations (IIC), standard deviations, the inter-item correlations matrix, a desirable alpha level of 0.8 set a priori, and Cronbach's alpha if the item is deleted informed decisions about the reliability analysis of the subscales.

Discussion and Conclusion

Discussion

This study sought to understand what questions would be important in shedding light on the complexity of sociocultural factors that affect Black undergraduates' self-efficacy in science. More specifically, this study combined constructs that are often studied in isolation or in concert with one or two others—self-efficacy, science identity, value, persistence, and culture. These constructs were refined during implementation to focus on expectancy, self-efficacy, familial self-efficacy, cognitive self-efficacy, and commitment. This is the first self-efficacy instrument in science education implemented at an HBCU with a predominantly Black population and that was created with considerations of the cultural, social, and historical impact of being Black in STEM.

The results show that for a more uniform context that favors and supports the performance of Blacks, the initial constructs are more intricately related to an individual's self-efficacy.

Questions that were initially identified as identity, value, and persistence more accurately reflected an individual's expectancy—that is whether one saw oneself becoming a scientist or whether becoming a scientist would be useful or if an individual looked forward to working in a lab was indicative of an "expectancy." Moreover, questions related to culture, value, and general self-efficacy were better indicators of other dimensions of self-efficacy—cognitive self-efficacy, familial self-efficacy, and self-efficacy. Cognitive self-efficacy focuses on the extent of agency and empowerment during learning. An individual is either willing to change how they learn, has already changed the way they learn, and is influenced by seeing others like themselves do challenging things—implicates their cognitive self-efficacy.

The impact of familial self-efficacy was more important as pilot questions that surrounded scientists in the community did not make it to a final set of questions in this questionnaire. The findings show that the question *I doubt my own ability to do well in science when others have difficulty* affects scores in overall self-efficacy, whereas the question *I know I can do well when I see people like me able to do something challenging* affects scores in cognitive self-efficacy. Whether or not an individual looked forward to working with people in STEM or planned to pursue an advanced degree right after college indicates a commitment. The individual's science identity was connected to their familiarity with scientists in their local community and whether or not they considered the language of science a part of their everyday language or as foreign.

The implications and role for modeling cannot be underestimated. The positive correlations between expectancy and familial self-efficacy implicate the importance of modeling which Bandura (1997) indicates can convey coping strategies. The negative correlations of familial self-efficacy or vicarious experiences with cognitive and general self-efficacy are supported by Estrada et al.'s (2011) findings that self-efficacy as an indicator of persistence breaks down when science identity and feelings of belonging are thrown into the mix. Thus, socially and culturally related factors are important indicators of science identity and feelings of belonging, which affects persistence in STEM. The negative experiences of Blacks in STEM (Brown et al., 2016; Carlone & Johnson, 2007) coupled with the lack of exemplars could explain the negative correlations with familial self-efficacy (Table 6).

Limitations and Future Directions

Some of the questions chosen would not typically be found in these types of questionnaires. However, the questions reflect a combination of findings from the research literature as well as observations by STEM faculty at an HBCU. For example, some might consider the pursuit of graduate studies as too narrow a measurement of commitment. However, these questions were influenced by the experiences and observations of one biology faculty who has taught in this HBCU for over 40 years. His observations suggest that Black

Table 6 Summary of reliability analysis for self-efficacy subscales

Subscale	No. of items	Alpha	Avg. IIC	SD (IIC)	Mean	SD
Expectancy	3	.811	.588	.126	3.68	.390
Self-efficacy	3	.749	.499	.077	3.65	.415
Self-efficacy (familial)	3	.768	.524	.095	3.37	.558
Cognitive self-efficacy	3	.637	.369	.145	4.204	.298
Commitment	3	.670	.404	.084	4.28	.148
Identity/agency	3	.789	.555	.240	3.325	.434

students who do not immediately continue into an advanced degree seem more likely not to persist in STEM. An understanding of the plight of Black students in HBCUs shows that financial concerns impact students' commitment, and thus, socioeconomic influencers are critical to the social and historical underpinnings of Black students. Future studies will conduct interviews with students to better understand whether or not using questions that focus on degree pursuits too narrowly defines commitment. Future interviews and further exploration into the data will also explore the multiple factors that affect students' expectancy. For example, where high cognitive self-efficacy correlated with low expectancy, was being a STEM or non-STEM major a determinant or were there other factors at play?

The findings show that questions related to culture (familial self-efficacy and identity), self-efficacy, identity, commitment, and expectancy (value) are all intricately intertwined. The reduced questions will be further tested on a population with varied research experience to include larger numbers sophomores, juniors, and seniors from different STEM majors. This will be triangulated with qualitative interviews. Further analyses will explore the relationships between expectancy, commitment, identity, and the different self-efficacies to understand their implications for culture, value, and persistence, and their connections to self-efficacy and identity in blacks at HBCUs.

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