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Moving Beyond the Experiment to See Chemists Like Me: Cultural Relevance in the Organic Chemistry Laboratory

Sinead Younge, Danielle Dickens, Leyte Winfield, and Shanina Sanders Johnson*

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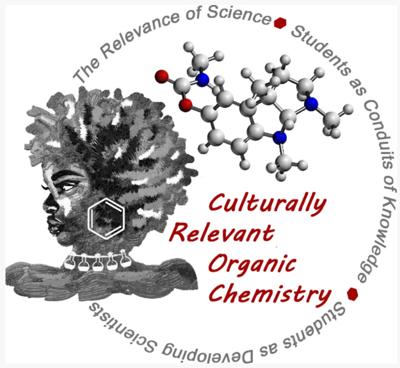
ABSTRACT: Culturally relevant pedagogy and critical race feminism can be utilized to challenge the inequality and masculine nature of chemistry. Such an approach is needed to increase the representation of Black women in STEM and can be leveraged to create a curriculum that addresses the lived experiences of these individuals. This approach can shift the dynamics of the learning environment by allowing students to take the lead in creating knowledge and, in the case of students, seeing how other Black women experience and contribute to the field of chemistry in meaningful ways. In acknowledging the intersection of gender, race, and personal interest in connection with culturally relevant pedagogies, learning strategies have been created to engage Black women. Student interview and survey data revealed their interest and growing knowledge of the relevance of science. The information also showed that completing the culturally relevant lab activities helped students see themselves as developing scientists. Based on the response to the activities, it is believed that the intentional design of an academically challenging and inclusive curriculum will enhance students' perception of themselves as scientists.



KEYWORDS: *Second-Year Undergraduate, Organic Chemistry, Women in Chemistry, Student-Centered Learning*

Spelman College, a leader among Historically Black Colleges and Universities (HBCUs) and liberal arts colleges alike, is an institution whose mission is to cultivate the talent of Black women and is uniquely positioned to respond to the need for diversity in STEM. Black women earned 4.9% of STEM Bachelor's degrees in 2018, while women earned 44.7% of Bachelor's degrees overall.[1] In the same year, Black women earned 1.2% of doctoral degrees with women earning 35% overall. Inclusion of individuals with diverse thoughts and experiences is needed to advance science and to promote equity in the STEM workforce. Data has shown that diverse teams are more successful and produce more impactful scholarship.[2−5] Teams that include individuals with backgrounds that are underrepresented in STEM have also been shown to produce higher rates of scientific novelty.[6] However, their scientific achievements are not always acknowledged and in fact are devalued and do not lead to the same career success as similar work from individuals overrepresented in STEM.[6] For chemistry, the manner in which the subject is traditionally taught promotes the dominant culture while excluding the experiences of underrepresented minorities. This can unintentionally alienate students that are not included in the majority; thus, the students actively practice science but they do not see themselves represented.[7] Utilizing teaching strategies that connect culture, real world problems, and student interests can serve to mitigate this teaching practice and promote diversity, equity, and inclusion and serve to increase the number of Black women participating in STEM.

The current literature on Black college women in STEM often compiles their academic essentialism with that of Black college men to address the racial components and that of white women to address the gender component.[8−10] There is a small but growing body of research that examines Black women in STEM,[9,11−15] but most often, efforts geared toward Black women are encapsulated in the experiences of women of color.[16−18] Combining these different groups prevents the characterization of Black women's success in STEM in a way that can be translated into more inclusive classroom environments.[11] Such information is needed to create meaningful experiences for Black women in STEM educational programs and address their woeful underrepresentation in these disciplines. Moreover, it is critical to acknowledge how their intersectional identities influence their experiences in STEM education[19] and how pedagogical experiences can be created to celebrate these identities.

Research has demonstrated that contextual or environmental factors have the power to shape undergraduate students' experiences[20] and specifically Black women's success in STEM. Therefore, the work presented here sought to leverage such

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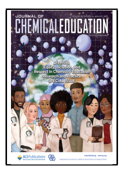

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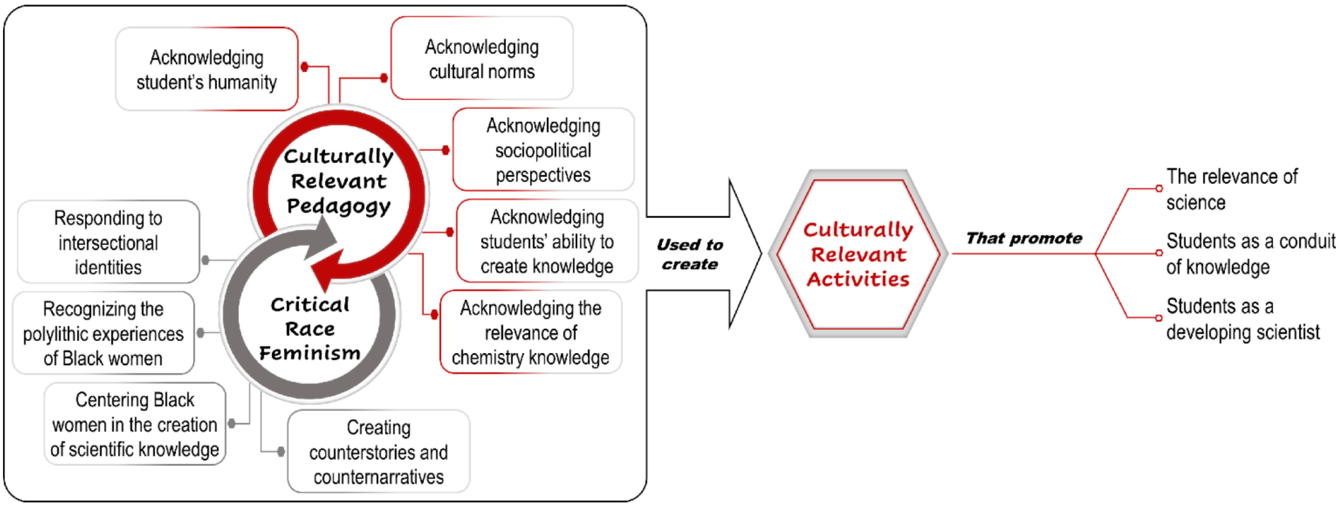

Figure 1. Intersection of culturally relevant pedagogy (CRP) and critical race feminism (CRF) in organic laboratory activities.

factors to humanize the organic chemistry curriculum in the context of the Black cultures and the identities of women of African descent. To create content appropriate for this purpose, the authors were guided by the tenets of culturally relevant pedagogy and critical race feminism. Both place Black women at the center of the experience to give space to a group of individuals, Black women, who are underrepresented in STEM by both gender and race.

CULTURALLY RELEVANT PEDAGOGY (CRP)

CRP was employed to contextualize activities in the organic chemistry laboratory. The tenets of CRP are *academic success*, *cultural competence*, and *sociopolitical consciousness*.[21] Coined by Gloria Ladson Billings, CRP seeks to "link principles of learning with a deep understanding of (and appreciation for) culture".[22] This asset-based pedagogy recognizes and values the prior knowledge and skills that students bring with them to the classroom. It also acknowledges the wealth of information that is derived from students' social and community networks. Furthermore, it has been suggested that science or STEM identity can be influenced by how well an individual integrates STEM into their sociocultural context.[7] Thus, the cultivation of a science identity among Black women was also explored during these laboratory activities. Science identity in this context indicates if students see themselves as scientists and feel that other scientists accept them as such.[23]

Students bring multiple identities to the classroom, and the curriculum should integrate these identities. Research in science disciplines supports the notion that culturally relevant teaching should be used in these fields.[24−28] It has been shown that academic success alone is not sufficient in encouraging underrepresented students to persist in STEM. Their identities, world views, and personal experiences must also be considered.[29,30] Activities that include culturally relevant elements allow students to construct chemical knowledge from an identity-based perspective. Such pedagogical approaches also demonstrate the applicability of chemistry toward addressing national issues and examining inequities in social and educational institutions. The sociopolitical aspect is one that Ladson-Billings has critiqued in recent years because individuals who have adopted CRP have done so in a manner that disregards the significance of the social/political component in pedagogy.[31] In the effort described here, CRP was utilized in organic chemistry to enhance the cultural relevance of laboratory activities that nurture science identity among Black women.

CRITICAL RACE FEMINISM (CRF)

To illuminate the identity-related experiences of Black women in STEM education, an intersectionality lens was utilized. The theory is well-established for exploring how multiple systems of oppression interlock to influence experiences of power and privilege.[32] Within STEM fields, an intersectional framework suggests that women of color are susceptible to experiencing the combination of racism and sexism,[33] known as gendered racism.[34] This phenomenon creates a double bind of marginalized identities, that of being both Black and a woman.[35−37] Yet, research has shown that when Black women's professional persona is compatible with their gendered racial identity, it can enhance their general academic and STEM success.[38,39] The double bind may influence how these individuals see themselves as scientists and their persistence in STEM fields. Building on intersectionality and critical race theory, CRF posits that race and gender function together in structuring social inequality.[40,41] CRF disentangles Black women's existence from the essentialism of critical race theory and feminism, recognizing their lives as unique from Black men and white women, respectively. Documented through legal precedence, the framework informs both theory and practice, shepherding an interdisciplinary approach to creating spaces and experiences for Black women. Evans-Winters and Esposito argued that CRF is helpful for studying, analyzing, and celebrating the experiences of Black women students, including the tenacity demonstrated by Black women's very existence and thriving in STEM.[42]

DESCRIPTION OF CULTURALLY RELEVANT ACTIVITIES

The activities described herein respond to the tenets of both CRP and CRF by implementing instructional materials that allow students to investigate every day applications of organic chemistry. The activities center students' intersectional identities and provide an opportunity for these individuals to see themselves as creators and as communicators of relevant scientific knowledge as well as science practitioners. In this way, the activities are believed to humanize the organic

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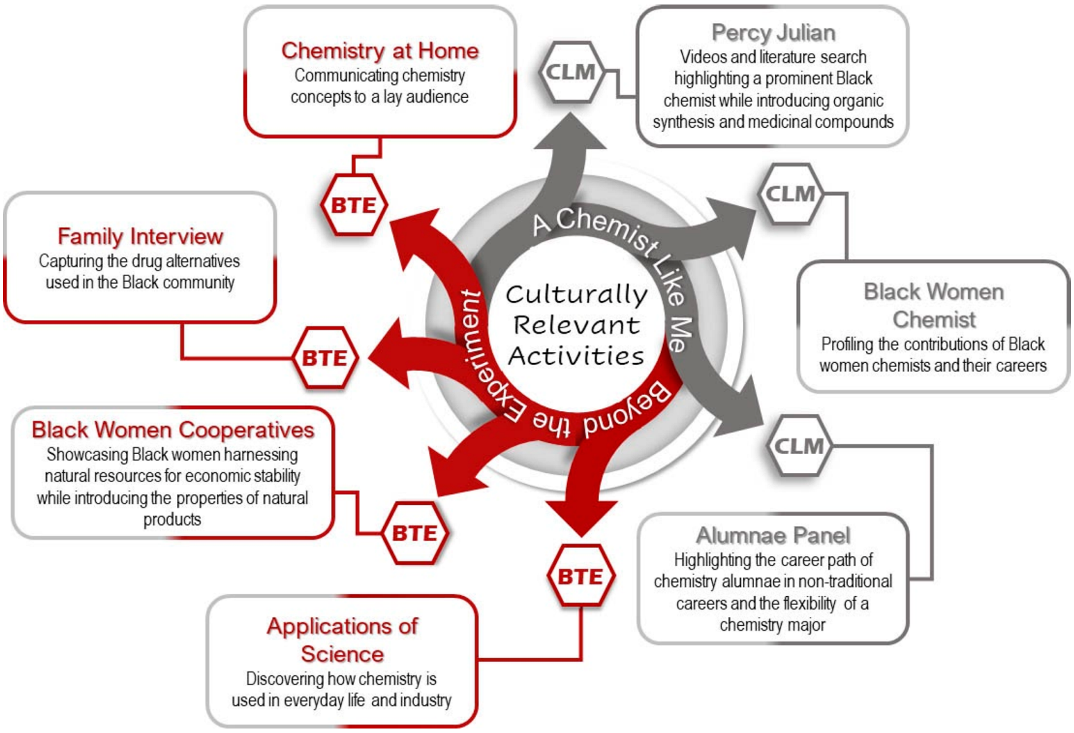

Figure 2. Overview of culturally relevant activities. The activities are characterized as A Chemist Like Me (CLM) and Beyond the Experiment (BTE).

chemistry curriculum by centering the knowledge and diverse perspectives of Black college women in conversations of importance to the culture and current times, offering counter-narratives to mainstream chemistry. The goals of such activities aim to promote the relevance of science, students as a conduit of knowledge, and students as a developing scientist, Figure 1.

A Chemist Like Me

During Fall 2020, culturally relevant activities were implemented through *A Chemist Like Me and Beyond the Experiment* modules, Figure 2. On the first day of the course, instructors showed students a video about Percy Julian, a Black chemist.[43] This video was part of NOVA: *Percy Julian: Chemistry and Civil Rights* and served as an introduction to organic chemistry techniques. The film also introduced the chemistry that made Julian a prominent synthetic chemist. A literature search assignment was combined with the video to allow students to further explore molecules from Julian's work.[44−46] Later in the course, students viewed an additional video from the series focused on Julian's academic career and the challenges he faced due to racism and segregation.[43] In line with CRP, such an approach served to highlight the social and political challenges that existed in chemistry during Julian's time and to demonstrate the strategies he used to overcome these challenges.

While the Percy Julian series served as a prelude for the *A Chemist Like Me* module, the cornerstone of the module centered on Black women chemists, thereby operationalizing CRF. Students worked in virtual groups to identify a Black woman chemist. The group created a profile of the individual based on an interview or information from the literature and social media platforms. The module culminated with a virtual panel of Spelman chemistry alumnae who have careers in corporate America. Three panelists shared their personal and professional paths and the challenges of being a Black woman in a corporate position. Most importantly, the panelists described how their academic training as a chemistry major at Spelman College prepared them for their career path. The panel exposed students to the versatility of a chemistry degree and nontraditional careers attainable with a STEM background. In line with CRF, this panel served to counter the stereotypical images of a scientist or chemist by providing students an opportunity to interact with scientists who share their cultural background.

Beyond the Experiment: Alternative Pain Relievers Interview

The *Beyond the Experiment* module extended students' understanding of the application of chemical concepts in their community and personal life. The first activity in this module was paired with the Synthesis of Aspirin experiment. The instructor provided background on the origins of aspirin and its relation to the medicinal properties of willow bark. Subsequently, students were given information about the baobab trees and its vitamin-filled fruits, its rise to global prominence as a superfood, and use in traditional medicine. Students viewed videos that illustrated how the export influenced the economy and the ecosystem of Senegal and about a cooperative of women that used the baobab to improve their economic standing.[47,48] After students learned about the baobab natural product and completed the Synthesis of Aspirin experiment, they explored the use of natural or alternative remedies in their communities by interviewing a family member, typically a woman, about alternative remedies used for pain relief. Questions asked included: *How was the remedy prepared?* and *Was the use of the remedy a family practice?* Students then researched the treatment to investigate any medicinal properties. The assignment stemmed from the knowledge that African Americans routinely use alternative or complementary medicines for prevention and treatment of ailments, a practice that has some basis in medical discriminatory practices.[49,50] Sharing the interview results with their classmates allowed students to learn about alternative therapeutics from different regions and cultures. Students also observed overlap in remedies. Examples that students shared included Cerasee (Bahamas), Noni juice (Southeast Asia), soursop (Jamaica), and peppermint oil (USA). Students could also elect to research an alternative medicine from the literature in place of interviewing a family member. Examples from these submissions included golden milk (India), lavender, and other essential oils. Overall, this activity allowed students to engage with members of their community and bring the knowledge they gained into the classroom to lead discourse, enhance their peers' learning, and improve their peers' cultural competence as it relates to cultures within the African diaspora. In this way, the activities related to alternative medicine and capitalized on the hallmarks of both CRF and CRP.

Beyond the Experiment: Chemistry at Home – Dyes in Your Everyday Life

The Dyes in Your Everyday Life module was related to two experiments performed by the students involving the extraction of chlorophyll from spinach and thin-layer chromatography (TLC) of food dyes. After completing the extraction experiment, where they isolated chlorophyll and utilized the compound as a paint, students were provided with a list of industries and topics that use dyes. They were required to research the use of dyes as it relates to the industry or topic selected and to describe the use of dyes in their lives. Selected topics included the application of natural and synthetic dyes in food, textiles, cosmetics, and medical applications. For everyday use, students recognized the ubiquity of dyes in their clothing and personal care items. Many of the students expressed surprise and some concern with the practice of using dyes to make food more appealing in the U.S., given the controversies surrounding such practices in other countries (e.g., bans and warnings related to Yellow 6, Yellow 5, and Red 40). In addition, students discussed the consumption of food dyes in relation to lifestyle. Most notably was the opposition to cochineal or carmine dyes, which are derived from crushed bugs, by those following a kosher, vegan, or vegetarian lifestyle. By exploring these aspects of dyes, students were able to increase their cultural competencies and demonstrate the relevancy of chemistry concepts.

Beyond the Experiment: Chemistry at Home – Infrared (IR) Spectroscopy

In the final Beyond the Experiment module, students created a one slide presentation explaining a current application of IR spectroscopy. The presentation included a digital artifact (i.e., a short video, graphic, or news story) to illustrate the application of the analytical tool. Innovations such as remote controllers, contactless thermometers, cooking devices, forensics detectors, thermal imaging cameras, Apple airpods, infrared saunas, and milk analysis devices were featured in many presentations. Students also presented on technologies such as the automatic soap dispensers and face ID, technologies which have come under some scrutiny given issues related to the detection of darker skin colors. The module illustrated ways in which organic chemistry concepts can be used to explain technologies that impact everyday life. The activity allowed students to serve as the authority on their topic and facilitated knowledge transfer within the course, a cornerstone of CRF.

Beyond the Experiment: Chemistry at Home Competition

Near the end of the semester, students completed a video assignment which required them to reflect on their experiences completing the organic chemistry laboratory and the culturally relevant activities. The assignment could be submitted for an optional social media competition. Students were asked to identify their favorite experiment, describe how it works for a lay audience, and describe its connections to everyday life. For students that elected to participate in the competition, five finalists were chosen by the organic chemistry faculty based on the established guidelines. The videos were posted on social media and the winner was chosen based on relevance to the assigned topic, the student's ability to connect chemical concepts to societal topics, and the ability of the post to generate substantive comments and views. Posts from the finalists garnered more than 190 comments and 1300 views during Fall 2020. This activity allowed students to present scientific knowledge and to have that knowledge celebrated in a public platform. Both the performance and recognition are essential in developing science identity[23,51] and further reflects the adoption of CRP into the laboratory curriculum.

■ LOGISTICS RELATED TO CULTURALLY RELEVANT ACTIVITIES

Setting

This work is part of a National Science Foundation Targeted Infusion Project at Spelman College. The institution is a fully accredited, private liberal arts college dedicated to educating women of African descent. With an average annual enrollment of 2100 students and an average graduating class of 500 students, less than 200 of Spelman's graduates (excluding psychology) represent STEM disciplines.[49,50] Nevertheless, the College stands as a leader for educating Black women who excel in science careers and is the top producer of Black women graduates who earn STEM doctorates.[52−61] The institution runs five sections of the laboratory in the fall semester and three in the spring, each section having a maximum enrollment of 16 students. Fall sections were overenrolled, but the spring sections were limited to the maximum enrollment although laboratories were held virtually both semesters. Students worked individually unless otherwise indicated.

Laboratory Experience

The activities were implemented during Fall 2020 and Spring 2021. During that time, the organic laboratories at Spelman College were held remotely with synchronous and asynchronous components. Students previewed PowerPoints and answered prelab questions before the synchronous session where they received an instructor-led review of laboratory techniques. The session was also used to encourage student collaboration and to outline experiments that would be completed asynchronously. The experiments included simulations, videos, and at-home experiments. Student presentations and or reports on the Beyond the Experiment modules, described below, and other assignments were also completed asynchronously.

Participants

The assessments and data collection reported here were approved through the Spelman College Institutional Review

Board. All students enrolled in the organic chemistry laboratory course for Fall 2020 and Spring 2021 were required to complete the culturally relevant activities but could opt out of the inclusion of their work in the publication of outcomes. Both quantitative and qualitative data from students enrolled in an organic chemistry lab courses in Fall 2020 (n = 61) and Spring 2021 (n = 48) were collected. A convenience sampling strategy was used to recruit students for surveys and interviews. Students enrolled in the laboratory were sent a consent form and a link to the online survey via email. A convenience sample of students (n = 7) who completed the quantitative surveys was recruited to participate in the interviews.

ASSESSMENT

Quantitative Assessment of Science Identity and Cultural Relevance

Quantitative data were collected using scales that have been modified for use with Black women. The instruments were programmed into an online data collection and management platform (Qualtrics),[62] and links to the consent form and survey were sent to all students enrolled in the course at the beginning of the semester and the end of the semester. Students received assignment points at the beginning of the semester for completing the survey. However, they did not receive assignment points at the end of the semester.

Students' beliefs (identity, belonging, and agency) about their role in the scientific paradigm were measured using the Scientist Centrality Scale, adapted from the racial centrality subscale of the Multidimensional Model of Black Identity (MMBI) Inventory of Black Identity.[63,64] Scientific identity was measured using a subscale of the Scientist Centrality Scale, an 8-item subscale used to assess the importance of being a scientist (a student in the sciences).[64] Using a modified 4-point response scale, students rated their agreement with each item (e.g., *In general, being a scientist is an important part of my self-image* or *I have a strong connection to other scientists*). The sample (n = 87) is not adequate to conduct a factor analysis to explore scale reliability and validity; however, one will be conducted once two more waves of data are collected. Surveys were collected at the beginning and the end of the semester during the 2020−2021 academic year. Pre- and postsurveys were also collected for the *A Chemist Like Me* Panel Discussion.

Quantitative Data Analysis

The quantitative data were transferred into the Statistical Package for the Social Sciences (SPSS) version 27.[65] Data were cleaned and assessed for any missing data or outliers. Descriptive analyses were conducted to determine the distributions of the data.

Qualitative Assessment of Science Identity and Cultural Relevance

The qualitative data collection protocols were developed by the authors. The interview protocol is included in Supporting Information. Virtual interviews were conducted in late December 2020 to March 2021. Interviews lasted approximately 15 to 20 min. The qualitative data were recorded and transcribed by the graduate research assistant. Participants were sampled until saturation or when fresh data were no longer revealed. Data were analyzed using an open coding strategy including data checking for verification by one of the authors and the graduate student who assisted in conducting the interviews.

RESULTS AND DISCUSSION

Survey Outcomes

Quantitative data were collected to gather demographic information on the interview participants and characterize their initial science identity, Table 1, (demographics detailed in Supporting Information). Most students in the sample were third-year students. Due to the low postsurvey response rate, the quantitative data was not statistically analyzed for changes within a semester.

Table 1. Represents the Total Percentage of Respondents Who *Somewhat* or *Strongly Agreed* to the Statements Relating to Science Identity

	Fall 2020-Post (n = 10)		Spring 2021-Post (n = 39)	
	Somewhat Agree (%)	Strongly Agree (%)	Somewhat Agree (%)	Strongly Agree (%)
In general, being a scientist is an important part of my self-image.	64	18	35	15
Being a scientist is an important reflection of who I am.	55	27	43	8
Being a scientist has *very little* to do with how I feel about myself.	9	9	30	28

Following the *A Chemist Like Me* panel, students were queried to determine the extent to which the event influenced their thoughts about future careers, the centrality of science, and their science identity. Many of the respondents indicated that the event contributed to their sense of science identity and impacted how they viewed science careers, Table 2. More than 78% of the respondents indicated that the panel affirmed their choice of a future career. Additional information from *A Chemist Like Me* can be found in the Supporting Information.

Table 2. Responses to Selected Items from the *A Chemistry Like Me* Survey (n = 52)[a]

Item	Response	Std Dev
This panel contributed to my sense of identity as a scientist.	3.32	0.71
After the panel, I have ideas about using my STEM major in some new way that I did not previously consider.	3.32	0.69
The panel helped me affirm my desired career path.	3.05	0.70

[a]Likert scale: 4 = Strongly Agree. 3= Agree, 2= Disagree = 2, 1= Strongly Disagree.

One group of students also rated the culturally relevant modules, Table 3.

Table 3. Mean of Respondents *Who Reported Somewhat Liking or Extremely Liking the Culturally Relevant Modules*

	Post (n = 39)[a]
Dyes in Your Everyday Life	M = 4.05, SD = 1.16
Alternative Pain Relievers Interview	M = 3.89, SD = 1.48
Infrared Spectroscopy	M = 3.37, SD = 1.48
Percy Julian Video	M = 3.34, SD = 1.32

[a]5= Extremely, 4= Somewhat, 3= Neutral, 2 = Slightly, 1 = Not at all.

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Qualitative Findings: Approach and Themes Constructed

A phenomenological approach was employed that seeks to understand the meaning of experiences based on participants' perceptions. The semistructured interviews were analyzed by hand using a grounded theory technique.[66] An open-coding scheme[67] was used where the researchers first reviewed the interview data for major concepts or themes. Next, the researchers conducted axial coding, reviewing codes for themes that emerged and the relationships between the themes. Categories were established to position the themes within the CRF and intersectionality frameworks.

All interviews were conducted by the first author and a graduate research assistant. The first author conducts program evaluation and research on pedagogy in higher education with a focus on the role of contextual factors on student development. As a Black woman trained in STEM, the first authors' experiences inform her connections with the undergraduates interviewed. The graduate research assistant was a Black woman who was studying anthropology and has an undergraduate minor in health, medicine, and society. The interviews were transcribed and the participants were given pseudonyms.

Qualitative Validity and Triangulation

The use of two researchers for analyzing the qualitative data ensured the trustworthiness of the data or qualitative validity. The researchers discussed the codes and their operational definitions in addition to reviewing one another's codebooks. Two transcripts were used to compare codes and resolve any discrepancies. The qualitative data were also examined simultaneously with the quantitative data for triangulation purposes. The approach identified four major themes that emerged from the data: (1) Perceived Science Credibility, (2) Learning community, (3) Culturally Relevant Modules, and (4) Science Identity.

Student Perceptions of their Scientific Identity. As illustrated in the word cloud, Figure 3, students interviewed spoke openly about what it meant to be a scientist, their perceptions of the laboratory experiences, and their thoughts about trusting science. Most reported that the credibility of a scientist is largely dependent on them being a white male and that individuals who are not are less likely to be seen as trustworthy. When asked, "What factors determine if you trust a scientist?" participants described factors such as affiliation and publication. However, they also understood that women and people of color are *trusted* less than their White counterparts. One participant stated,

> *People tend to trust men more with science. Women are gaining footing in science (but I'm not sure if that is because I go to an HBCU). Race plays a role in perceived credibility. Black women are the most educated group, but we are still overlooked in the science world, but middle Eastern and White people are more praised in science. -Janelle, Senior Biology Major, Pre-Dental*

Another participant added,

> *As a Black woman, I am more hesitant to take information from someone who does not look like me. Certain groups of people are not taken seriously. I'd rather take information from someone who looks like me. -Lisa, Junior Biochemistry Major, Pre-Med*

One participant described how she brings her White mother to her doctor's appointments to gain more credibility as a patient. Alongside this sobering reality, one participant explained that the social movements that occurred in the summer of 2020 helped to bring more credibility to scientists of color.

Most participants in the sample were also more trusting of scientists who were more like themselves. However, participants reported that men and people who are not of color tend to be more trusted in the role of scientist by the larger society. These findings are consistent with the Phenomenological Variant Ecological Systems Theory (PVEST), which is an identity-focused theory situated within culture and ecology as it relates to human development and engagement.[68] The participants' lived experiences and developing science identity must account for the context in which they are learning.

Based on student interviews, it is believed that the learning environment that was shaped by the culturally relevant activities created a supportive academic structure that validated students' identities and experiences while allowing them to embrace different ways of learning. Consistent with CRF, The *Beyond the Experiment* modules allowed students to lead discussions about chemistry that were centered on their cultural backgrounds, interests, and families as Black women. Students were able to share personal stories that allowed elements of their individual, intersectional identities to be expressed and demonstrate value for their culture while builing community within the course. Students rated the modules as shown in Table 3.

Figure 3. Non-narrative summary of the composite interviews.

Science Identity

Carlone and Johnson proposed a model for science identity that applies to underrepresented women in science.[23] They proposed that in addition to racial, ethnic, and gender identities, science identity is informed by three factors: performance, recognition, and competence. In the interviews, students spoke about being recognized as a scientist, by themselves and by others, and they discussed the level of competency required to consider themselves as scientists. Participants were asked, "What comes to mind when you hear

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the term scientist?" A prominent theme that emerged was that a scientist conducts scientific research, asks questions, and publishes. When asked, "Do you consider yourself a scientist", many participants agreed that they engage in scientific behaviors. However, some of the students in the sample were not comfortable embracing the title of scientist, despite reportedly engaging in the activities that they reported makes one a scientist. Some participants reported that they could embrace the title once they graduated, attended graduate or medical school, or started their careers. One student reported,

> *If I did a graduate school program, it would be easy for me to say, yes, I've finally reached that level once you reach a certain level, like with a job or grad school. I think of myself as a scientist in training. -Aisha, First Year, Chemistry Major, Dual Degree-Engineer*

Aisha went on to state,

> *I never felt like a scientist until I got to Spelman and I got into this community. You know, there's not a lot of Blacks in STEM, there's not a lot of Black women in STEM. So, seeing myself represented, it is a good feeling and that is something I want to advocate for and something I'm passionate about because we definitely need more representation. So, knowing that, I feel more confident in myself in STEM, and as a scientist.*

Another student added,

> *I try to [see myself as a scientist] now because in a conversation in the organic chemistry lab last semester, at which point are you a scientist? I think our professor said when you see yourself, when you put yourself in the position to be a scientist, when you are taking steps toward the career that you want or when you have experience in particular science fields, you can kind of consider yourself a scientist so I would say that I'm a budding scientist. -Denise, Third Year Biology Major, Pre-Medicine*

The statements are consistent with the notion that science identity is a developmental process that unfolds over time and that the environment informs the identity the individual develops.[69] By employing an intersectional and critical race feminist framework that suggests that Black women are susceptible to experiencing gendered racism, the findings uncovered that the participants described here were not only aware of the future opposition they may have to face, but they also engender the belief that they will have to receive additional training to be seen as credible or trustworthy scientist. Participants in the sample were familiar with what activities scientists engage in, and despite engaging in those activities (e.g., developing a research question or hypothesis, collecting and analyzing data, using the scientific method), the students were not prepared to consider themselves scientists; instead, they were more comfortable embracing the term "scientist in training". This observation is in line with what is noted in the literature about science identity among under-represented populations.[70]

Findings From Student Video Competition. For the video competition, students shared their favorite remote experiment, describing how the experiment works (techniques/properties), its connections to everyday life. The following quotes were extracted from the video submissions.

1. Experiment: The Extraction of Chlorophyll from Spinach. The student indicated liking this experiment "*because it gave me a better understanding of the chemistry occurring in everyday life*". The student went on to state, "*the experiment gave me ideas for how I could use things that are just lying around my house in order to create science experiments at home, traditionally before this I thought of science as being expensive and having to be done in a laboratory but after this, I realized that glassware that costs hundreds of dollars can easily be replaced with just things you have lying around in your kitchen...Things like that it really forced me to think outside the box and what I need in order to make science happen.*"

2. Experiment: The Extraction of Chlorophyll from Spinach. Another student stated, "*This semester in chemistry forced us to look beyond our normal scope and examine the chemistry that surround us...This experiment allowed me to see that we can analyze the components of any organic compound, there is organic chemistry everywhere around us. Doing these experiments allowed me to share with my family what I'm doing in the lab.*"

3. Experiment: The Extraction of Chlorophyll from Spinach. Another student stated, "*so being able to actually use what was created in the lab was something that was very different than what I've experienced before everything is very conceptual and practical but we lack application when we were in schools like real world scenarios so being able to like understand what an extraction does...*" The student went on to state, "*...so this is why that was my favorite experiment and it was just interesting to be able to interact with different things and feel like a chemist at home.*"

4. Beyond the Experiment Module: Alternative Pain Relievers. Another student stated, "*We actually got to interview people in our own homes so I got to talk to my family and I got to ask them all about organic chemistry and natural pain remedies so I interviewed my cousin xx who lives in Texas and she told me that she uses lavender oil for her migraines and she rubs on her temples like this and it makes her feel a whole lot better and so I was like oh wow that is so interesting so I did some research...*"

■ LESSONS LEARNED THAT CAN BE GENERALIZED TO OTHER INSTITUTIONS

Nurturing science identity must be intentional early in a student's matriculation. However, students' science identity is not cultivated in isolation. Being thoughtful and intentional about learning content, pedagogy, and learning environments can impact students' sense of self and their motivation to engage in coursework. Diversifying STEM curriculum and the scientists students learn about is one method of increasing representation in STEM and also impacts identity formation. Furthermore, allowing students to have experiences in the classroom that intersect between their gender, ethnicity, and the science curriculum is critical in inclusive teaching.

■ LIMITATIONS

The effort reported here used a self-report mixed methodology of quantitative and qualitative data. There was a significant amount of attrition from the pre- to postsurvey collection and were, therefore, only able to provide descriptive results of the survey data. In addition, the qualitative data were collected on a smaller sample size, consistent with qualitative methodologies. Given the approach, the findings may not and are not intended to be generalizable to a larger population. Instead, the findings may be distinctive for Black women at the institution but may have implications for those at other HBCUs and historically white institutions. However, further research is needed.

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■ CONCLUSION

While there have been efforts to make chemistry more inclusive for students who have marginalized race and gender identities, these individuals are still underrepresented in STEM.[71] Past research suggests that cultural, gender, and racial stereotypes can impede student's learning.[72] Moreover, it is argued that professors should move toward making STEM classrooms more welcoming for women of color.[73] The approach described here allowed students to share their personal stories and connect their learning and lived experiences. The effort reported here leverages the CRP framework to create laboratory-based learning activities and to understand how engaging in these activities influenced students' self-concept as scientists.

■ IMPLICATIONS AND FUTURE RESEARCH

The outcomes contribute to the dearth of literature on Black women in STEM, particularly around the concept of science identity and incorporating diversity into the curriculum. Continued research on Black women is warranted, and it is believed that the findings can help contribute to future studies. Interventions that promote the embracing of a science identity should be explored to improve the outcomes of women with other intersecting identities. In addition, placing the context of the curriculum in a way that speaks to greater representation and inclusivity is important for Black women, and other women of color, to cultivate a science identity.

Laboratory-related activities were developed that allowed students to demonstrate their relationship to the topic. In doing so, students brought artifacts representing their communities, families, experiences, and identities to bear on multicultural discussions of these topics. This allowed students to connect in a supportive learning environment that promoted the relevance of science, student knowledge dissemination, and nurtured their development as scientists. As such, the findings reported herein demonstrate how the convergence of institutional and societal factors impact and cultivate the development of a science identity among Black women undergraduate students attending a historically Black college.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00488.

Survey instruments (PDF)

Interview protocol (PDF)

Student demographics (PDF)

■ AUTHOR INFORMATION

Corresponding Author

Shanina Sanders Johnson − *Spelman College, Department of Chemistry and Biochemistry, Atlanta, Georgia 30314, United States;* orcid.org/0000-0002-7799-9858; Email: ssande15@spelman.edu

Authors

Sinead Younge − *Morehouse College, Department of Psychology, Atlanta, Georgia 30314, United States*

Danielle Dickens − *Spelman College, Department of Psychology, Atlanta, Georgia 30314, United States*

Leyte Winfield − *Spelman College, Department of Chemistry and Biochemistry, Atlanta, Georgia 30314, United States;* orcid.org/0000-0003-3719-5895

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.1c00488

Notes

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■ REFERENCES

(1) *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2021*; NSF - National Science Foundation, https://ncses.nsf.gov/pubs/nsf21321/report (accessed 2021-08-24).

(2) Heemstra, J. M.; Waterman, R.; Antos, J. M.; Beuning, P. J.; Bur, S. K.; Columbus, L.; Feig, A. L.; Fuller, A. A.; Gillmore, J. G.; Leconte, A. M.; Londergan, C. H.; Pomerantz, W. C. K.; Prescher, J. A.; Stanley, L. M. Throwing Away the Cookbook: Implementing Course-Based Undergraduate Research Experiences (CUREs) in Chemistry. *ACS Symp. Ser.* **2017**, *1248*, 33−63.

(3) Phillips, K. W. How Diversity Works. *Sci. Am.* **2014**, *311* (4), 42−47.

(4) Freeman, R. B.; Huang, W. Collaboration: Strength in Diversity. *Nature* **2014**, *513* (7518), 305−305.

(5) Freeman, R. B.; Huang, W. Collaborating with People Like Me: Ethnic Coauthorship within the United States. *https://doi.org/10.1086/678973* **2015**, *33* (S1), S289−S318.

(6) Hofstra, B.; Kulkarni, V. V.; Munoz-Najar Galvaz, S.; He, B.; Jurafsky, D.; McFarland, D. A. The Diversity-Innovation Paradox in Science. *Proc. Natl. Acad. Sci. U. S. A.* **2020**, *117* (17), 9284−9291.

(7) Herrera, F. A.; Hurtado, S.; Garcia, G. A.; Gasiewski, J. A Model for Redefining STEM Identity For Talented STEM Graduate Students. *VOCEDplus*, http://hdl.voced.edu.au/10707/229070.

(8) Liu, S.-N. C.; Brown, S. E. V.; Sabat, I. E. Patching the "Leaky Pipeline": Interventions for Women of Color Faculty in STEM Academia. *Arch. Sci. Psychol.* **2019**, *7* (1), 32−39.

(9) McGee, E. O.; Bentley, L. The Troubled Success of Black Women in STEM. *Cogn. Instr.* **2017**, *35* (4), 265−289.

(10) Wing, A. K.; Willis, C. A. Critical Race Feminism: Black Women and Gangs. *J. Gender, Race Justice*; SAGE Publications, 1997; p *1*.

(11) King, N. S.; Pringle, R. M. Black Girls Speak STEM: Counterstories of Informal and Formal Learning Experiences. *J. Res. Sci. Teach.* **2019**, *56* (5), 539−569.

(12) Thomas, J. O.; Joseph, N.; Williams, A.; Crum, C.; Burge, J. Speaking Truth to Power: Exploring the Intersectional Experiences of Black Women in Computing. In *2018 Research on Equity and Sustained Participation in Engineering, Computing, and Technology, RESPECT 2018 - Conference Proceedings*; Institute of Electrical and Electronics Engineers, Inc., 2018. DOI: DOI: 10.1109/RESPECT.2018.8491718.

(13) Johnson, I. R.; Pietri, E. S.; Fullilove, F.; Mowrer, S. Exploring Identity-Safety Cues and Allyship Among Black Women Students in STEM Environments. *Psychol. Women Q.* **2019**, *43* (2), 131−150.

(14) Ireland, D. T.; Freeman, K. E.; Winston-Proctor, C. E.; DeLaine, K. D.; McDonald Lowe, S.; Woodson, K. M. (Un)Hidden Figures: A Synthesis of Research Examining the Intersectional Experiences of Black Women and Girls in STEM Education. *Rev. Res. Educ.* **2018**, *42* (1), 226−254.

(15) Dickens, D. D.; Chavez, E. L. Navigating the Workplace: The Costs and Benefits of Shifting Identities at Work among Early Career U.S. Black Women. *Sex Roles* **2018**, *78* (11−12), 760−774.
(16) Alfred, M. V.; Ray, S. M.; Johnson, M. A. Advancing Women of Color in STEM: An Imperative for U.S. Global Competitiveness. *Adv. Dev. Hum. Resour.* **2019**, *21* (1), 114−132.
(17) Espinosa, L. L. Pipelines and Pathways: Women of Color in Undergraduate Stem Majors and the College Experiences That Contribute to Persistence. *Harv. Educ. Rev.* **2011**, *81* (2), 209−240.
(18) Johnson, D. R. Women of Color in Science, Technology, Engineering, and Mathematics (STEM). *New Dir. Institutional Res.* **2011**, *2011* (152), 75−85.
(19) Smith, K. C.; Boakye, B.; Williams, D.; Fleming, L. The Exploration of How Identity Intersectionality Strengthens STEM Identity for Black Female Undergraduates Attending a Historically Black College and University (HBCU). *J. Negro Educ.* **2020**, *88* (3), 407−418.
(20) Morton, T. R.; Nkrumah, T. A Day of Reckoning for the White Academy: Reframing Success for African American Women in STEM. *Cult. Stud. Sci. Educ.* **2021**, *16*, 485−494.
(21) Ladson-Billings, G. Toward a Theory of Culturally Relevant Pedagogy. *Am. Educ. Res. J.* **1995**, *32* (3), 465−491.
(22) Santiago, A. Focusing on Cultural Competency in STEM Education. http://www.informalscience.org/sites/default/files/FocusingonCulturalCompetenceinSTEMEducation.pdf (accessed 2019-03-05).
(23) Carlone, H. B.; Johnson, A. Understanding the Science Experiences of Successful Women of Color: Science Identity as an Analytic Lens. *J. Res. Sci. Teach.* **2007**, *44* (8), 1187−1218.
(24) Boutte, G.; Johnson, G. L. Culturally Relevant Teaching in Science Classrooms : Addressing Academic Achievement, Cultural Competence, and Critical Consciousness. *Multicult. Educ.* **2010**, *12* (2), 1−20.
(25) Kelly-Jackson, C.; Jackson, T. Meeting Their Fullest Potential: The Beliefs and Teaching of a Culturally Relevant Science Teacher. *Fac. Publ.* **2011**, *02*, 408.
(26) Johnson, A.; Elliott, S. Culturally Relevant Pedagogy: A Model To Guide Cultural Transformation in STEM Departments. *J. Microbiol. Biol. Educ.* **2020**, *21* (1), 05.
(27) Tanner, K. D. Learning to See Inequity in Science. *CBE Life Sci. Educ.* **2009**, *8* (4), 265−270.
(28) Tanner, K.; Allen, D. Cultural Competence in the College Biology Classroom. *CBE Life Sci. Educ.* **2007**, *6* (4), 251−258.
(29) Jones, T. C. Creating a World for Me: Students of Color Navigating STEM Identity. *J. Negro Educ.* **2020**, *88* (3), 358−378.
(30) Kozoll, R. H.; Osborne, M. D. Finding Meaning in Science: Lifeworld, Identity, and Self. *Sci. Educ.* **2004**, *88* (2), 157−181.
(31) Ladson-Billings, G. *Culturally Relevant Pedagogy 2.0: A.k.a. the Remix*; **2014**; *84*.74
(32) Crenshaw, K. Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics. *Univ. Chic. Leg. Forum* **1989**, 1.
(33) Ong, M.; Wright, C.; Espinosa, L. L.; Orfield, G. Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering, and Mathematics. *Harv. Educ. Rev.* **2011**, *81* (2), 172−208.
(34) Essed, P. *Understanding Everyday Racism: An Interdisciplinary Theory*; SAGE Publications, Inc.: Thousand Oaks, CA, 1991. DOI: DOI: 10.4135/9781483345239.
(35) Hammonds, E. *Thirty-Five Years after "The Double Bind," Obstacles Remain for Minority Women in STEM*; American Association for the Advancement of Science, https://www.aaas.org/news/thirty-five-years-after-double-bind-obstacles-remain-minority-women-stem (accessed 2021-04-27).
(36) Malcolm, S.; Hall, P. Q.; Brown, J. W. *The Double Bind: The Price of Being a Minority Woman in Science. Report of a Conference of Minority Women Scientists*; Warrenton, VA, 1976.
(37) Malcom, L. E.; Malcom, S. M. The Double Bind: The next Generation. *Harvard Educational Review*; Harvard University, 2011; pp 162−171. DOI: DOI: 10.17763/haer.81.2.a84201x508406327.
(38) Morton, T. R.; Parsons, E. C. #BlackGirlMagic: The Identity Conceptualization of Black Women in Undergraduate STEM Education. *Sci. Educ* **2018**, 1363 DOI: 10.1002/sce.21477.
(39) Espinosa, L. L. The Academic Self-Concept of African American and Latina(o) Men and Women in Stem Majors. *J. Women Minor. Sci. Eng.* **2008**, *14* (2), 177−203.
(40) Wing, A. K. *Critical Race Feminism: A Reader*; NYU Press: New York, 1997.
(41) Wing, A. K. *Critical Race Feminism*, 2nd ed.; NYU Press, 2003.
(42) Evans-Winters, V. E.; Esposito, J. ERIC - EJ885912 - Other People's Daughters: Critical Race Feminism and Black Girls' Education, Educational Foundations, 2010. *Educ. Found.* **2010**, *24*, 11−24.
(43) *NOVA: Percy Julian: Chemistry and Civil Rights*; PBS LearningMedia, https://pba.pbslearningmedia.org/collection/pj07-ex/ (accessed 2021-08-24).
(44) Perone, N. The History of Steroidal Contraceptive Development: The Progestins. *Perspectives in Biology and Medicine*; Johns Hopkins University Press, 1993; pp 347−362. DOI: DOI: 10.1353/pbm.1993.0054.
(45) Julian, P. L.; Pikl, J. Studies in the Indole Series. V. The Complete Synthesis of Physostigmine (Eserine). *J. Am. Chem. Soc.* **1935**, *57* (4), 755−757.
(46) Wilson, B. A.; Willis, M. S. Percy Lavon Julian. *Lab. Med.* **2010**, *41* (11), 688−692.
(47) Joshi. The women's collective that fights poverty with baobab trees, https://blog.ecosia.org/womens-collective-fight-poverty-baobab-trees/ (accessed 2021-04-22).
(48) *Fruit of African Baobab Tree Has Growing Global Appeal*; Voice of America - English, https://www.voanews.com/episode/fruit-african-baobab-tree-has-growing-global-appeal-3784956 (accessed 2021-04-22).
(49) Tamhane, A.; McGwin, G.; Redden, D. T.; Hughes, L. B.; Brown, E. E.; Westfall, A. O.; Conn, D. L.; Jonas, B. L.; Smith, E. A.; Brasington, R. D.; Moreland, L. W.; Bridges, S. L.; Callahan, L. F. Complementary and Alternative Medicine Use in African Americans with Rheumatoid Arthritis. In *Arthritis Care and Research*; NIH Public Access, 2014; Vol. *66*, pp 180−189. DOI: DOI: 10.1002/acr.22148.
(50) Barner, J. C.; Bohman, T. M.; Brown, C. M.; Richards, K. M. Use of Complementary and Alternative Medicine for Treatment among African-Americans: A Multivariate Analysis. *Res. Soc. Adm. Pharm.* **2010**, *6* (3), 196−208.
(51) Herrera, F. A. *A Model for Redefining STEM Identity for Talented STEM Graduate Students*; UCLA, 2012.
(52) *STEM at Spelman*; Spelman College, https://www.spelman.edu/academics/stem-at-spelman (accessed 2021-04-27).
(53) Spelman College - Profile, Rankings and Data; *US News Best Colleges*, https://www.usnews.com/best-colleges/spelman-college-1594 (accessed 2021-04-27).
(54) Thompson, A. N.; Scriven, O. A. *African American Women in Science: Spelman College as a National Model for Baccalaureate Degree Production in Models for Success: Successful Academic Models for Increasing the Pipeline of Black and Hispanic Students in STEM Areas*, Brooklyn, NY, 2008.
(55) Widener, A. Who has the most success preparing Black students for careers in science? Historically Black Colleges and Universities? https://cen.acs.org/education/success-preparing-Black-students-careers/98/i34 (accessed 2021-04-27).
(56) Widener, Andrea A Bright Spot in Training Black Scientists. *C&EN Glob. Enterp.* **2020**, *98* (34), 28−33.
(57) Fiegener, M. K.; Proudfoot, S. L. Baccalaureate Origins of U.S.-trained S&E Doctorate Recipients; US National Science Foundation, https://www.nsf.gov/statistics/infbrief/nsf13323/ (accessed 2021-04-27).
(58) Perna, L. W.; Gasman, M.; Gary, S.; Lundy-Wagner, V.; Drezner, N. D. Identifying Strategies for Increasing Degree Attain-

ment in STEM: Lessons from Minority-Serving Institutions. *New Dir. Institutional Res.* **2010**, *2010* (148), 41−51.
(59) Carter-Johnson; Frances Inniss, T.; Lee, M. E. HBCUs" Relevance in Diversifying the STEM Workforce.". *Divers. Issues High. Educ.* **2018**, *35* (2), 32.
(60) Winkle-Wagner, R.; Forbes, J. M.; Rogers, S.; Reavis, T. B. A Culture of Success: Black Alumnae Discussions of the Assets-Based Approach at Spelman College. *J. Higher Educ.* **2020**, *91* (5), 653−673.
(61) Estrada, M.; Burnett, M.; Campbell, A. G.; Campbell, P. B.; Denetclaw, W. F.; Gutiérrez, C. G.; Hurtado, S.; John, G. H.; Matsui, J.; McGee, R.; Okpodu, C. M.; Joan Robinson, T.; Summers, M. F.; Werner-Washburne, M.; Zavala, M. E. Improving Underrepresented Minority Student Persistence in Stem. *CBE Life Sci. Educ.* **2016**, *15*, es5.
(62) *Qualtrics XM, The Leading Experience Management Software*, https://www.qualtrics.com/ (accessed 2021-04-27).
(63) Sellers, R. M.; Rowley, S. A. J.; Chavous, T. M.; Shelton, J. N.; Smith, M. A. Multidimensional Inventory of Black Identity: A Preliminary Investigation of Reliability and Construct Validity. *J. Pers. Soc. Psychol.* **1997**, *73* (4), 805−815.
(64) Settles, I. H. When Multiple Identities Interfere: The Role of Identity Centrality. *SAGE J.* **2004**, DOI: 10.1177/0146167203261885.
(65) *SPSS Statistics*; IBM, https://www.ibm.com/products/spss-statistics (accessed 2021-04-27).
(66) Glaser, B.; Strauss, A. *Discovery of Grounded Theory: Strategies for Qualitative Research*; Aldine de Gruyter, 1967.
(67) Corbin, J. M.; Strauss, A. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 3rd ed.; Sage Publications: Los Angeles, CA, 2008.
(68) Spencer, M.; Dupree, D.; Hartmann, T. A Phenomenological Variant of Ecological Systems Theory (PVEST): A Self-Organization Perspective in Context. *Dev. Psychopathol.* **1997**, *9*, 817.
(69) Kim, A. Y.; Sinatra, G. M.; Seyranian, V. Developing a STEM Identity Among Young Women: A Social Identity Perspective. *https://doi.org/10.3102/0034654318779957* **2018**, *88* (4), 589−625.
(70) Nealy, S.; Orgill, M. K. Postsecondary Underrepresented Minority STEM Students⇔ Perceptions of Their Science Identity. *J. Negro Educ.* **2020**, *88* (3), 249−268.
(71) Gomes, M. de F. C.; Mortimer, E. F.; Kelly, G. J. Contrasting Stories of Inclusion/Exclusion in the Chemistry Classroom. *Int. J. Sci. Educ.* **2011**, *33* (6), 747−772.
(72) Baumgartner, L. M.; Johnson-Bailey, J. Fostering Awareness of Diversity and Multiculturalism in Adult and Higher Education. *New Dir. Adult Contin. Educ.* **2008**, *2008* (120), 45−53.
(73) Jackson, K. M.; Winfield, L. L. Realigning the Crooked Room: Spelman Claims a Space for African American Women in STEM. *Peer Rev.* **2014**, *16* (2), 9−12.

https://doi.org/10.1021/acs.jchemed.1c00488
J. Chem. Educ. 2022, 99, 383−392