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Research

Cultivating STEM engagement among African American youth: an exploration of secondary students' voices

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Abstract
In the United States, individuals who identify as Black are severely underrepresented in science, technology, engineering and mathematics (STEM) disciplines. This underrepresentation begins as early as middle school due to the stereotype of successful STEM students being white and male thus affecting Black students sense of belonging in STEM. The goal for this exploratory qualitative study was to understand the experiences of Black students in their science classes. Our choice of focus groups empowered these students, who have historically been missing from educational policy decisions, by providing them an opportunity to be part of the change they want to see in their schools. The results indicate that participants could see potential relevance in science and math classes but the structure of their current science classes (e.g., neglect and lack of care from teachers) affects their ability to actually experience this relevance. Despite this, many of our participants understood their value and believed that they "deserve more," which shows that we can improve the experiences for Black students in STEM and increase their representation in these disciplines.

Keywords Science education · Math education · Youth of color · Racism in STEM

1 Introduction

Black[1] individuals are severely underrepresented in science, technology, engineering and mathematics (STEM) disciplines in the United States (U.S.). Table 1 highlights the disparities related to representation in STEM fields compared to the U.S. population [1]. For example, Black people make up 3% of the STEM workforce, which is less than their 12% representation in the U.S. population. This is problematic because STEM disciplines are missing out on the untapped STEM talent and innovation that exists within these communities. In addition, these individuals are precluded from the financial benefits that STEM degrees can confer. This exclusion has an effect not only on the individual but also upon the families connected to that higher income earner. Beyond this capitalistic lens, STEM disciplines benefit from racial and ethnic diversity in many ways, including greater research innovation, higher-quality science, and improved impacts for other individuals in the general population who are from traditionally marginalized groups [2, 3].

[1] In the U.S., the terms Black or African American are used to refer to having origins in any of the Black racial groups of Africa. For the purposes of consistency, the authors have chosen to use the term Black for this paper.

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Table 1 Demographics of US STEM workforce compared to US population [1]

Race and sex	STEM workforce representation (%)	U.S. population representation (%)
White male	55	32
White female	18	33
Asian American male	12	2
Asian American female	4	2
Black	2	6
Black	1	6
Hispanic male	3	8
Hispanic female	1	8

It is important to highlight that our research is occurring in the United States, which has its own history and dominant narratives that influence the underrepresentation of Black people in STEM [4]. The story of the U.S. includes the enslavement of Africans who were brought to the U.S. against their will. Even after slavery legally ended, Black people faced the backlash of the Reconstruction period (i.e., lynchings) and continued dehumanization during the Jim Crow era, resulting in a dominant narrative of Black people being denied their human rights, including their right to an equal education [5]. In regard to STEM pursuits, research in the U.S. has highlighted several factors, which contribute to the lack of diversity and involvement of youth of color that begin early in students' educational trajectories, including but not limited to: lack of relevant, hands-on STEM experiences in elementary and secondary education [6–10]; lack of role models or connections to authentic STEM research for elementary, secondary, and college students [12–15]; and the culture within certain STEM disciplines that encourages the attrition and exclusion of underrepresented groups [16–18]. STEM disciplines, elementary and secondary education have long struggled with systems that define who belongs and who gets to succeed [19]. In the U.S., Black students have faced a history of abuse and neglect by science, which is compounded by the explicit and implicit views of a successful STEM student being white and male, which negatively influences Black students' ability to see themselves thriving within STEM [5].

When Black students lose interest in STEM in elementary and secondary school, the U.S. education system makes it difficult for them to reengage because STEM disciplines rely on a pipeline system. This system begins in secondary schools where STEM students must take courses in a prescribed order, relying on the successful completion of prerequisite courses. Consequently, if students do not see STEM as relevant or of interest to them in secondary school and do not take the prerequisite STEM courses (e.g., algebra, calculus), then they may be unable to successfully declare and complete a university STEM major [20]. Therefore, secondary school students are a crucial age group to include in research so that STEM educators can determine how to make STEM more relevant and interesting to them. Secondary school students' perspectives on STEM are also essential to understanding how the pipeline to STEM careers is shaped prior to high school graduation.

2 Conceptual framework

To frame students' interest and persistence in STEM, we utilized a STEM identity framework [7, 21, 22]. STEM identity was initially conceptualized by Carlone and Johnson [21] as science identity, wherein one develops competence in science, performs those competences and is recognized by perceived experts (e.g., teachers) as belonging in science or being a science person. Since then, STEM identity as a framework has broadened to encompass the ways in which power and privilege affect all individuals' opportunities to develop competence and have their performances recognized [4]. Individuals must first see the relevance of STEM to their lives in order to develop interest that motivates them to pursue science in school and in out-of-school activities. Consequently, persistence in STEM is due in part to a strengthening of one's STEM identity. And yet, for Black students, the examples used in science classrooms and stories about contributors to science, are often not relevant and/or White-centric, making it difficult for them to see themselves belonging [7, 22, 23]. In addition, individuals need to be recognized for their STEM performances in order for them to continue to see themselves succeeding in STEM [10, 17, 24, 25]. In school spaces, certain performances are accepted as legitimate and this legitimacy is often aligned with the dominant narrative that is controlled by racism and sexism, leading to Black

students feeling like imposters or having to change the ways in which they perform STEM to be accepted as our literature review will demonstrate [15, 22].

3 Literature review

Although our research takes place in the United States, it is important to point out that research in Germany [26], Spain [27], Canada [28, 29], and the United Kingdom [11, 23], all point to the structure of science and math classes which result in a lack of relevance and engagement for students from low-income families and/or girls. In addition, these studies point to the gender stereotypes that affect how teachers position and recognize them as legitimate STEM people [11, 23]. Researchers in Canada [30] and the United Kingdom [31], have focused on the role of race and racism in STEM identity construction. Rahm and her colleagues [30] focused on the STEM identity trajectories of girls of color who were also immigrants to Canada as they participated in an afterschool science program. The authors found that these girls struggled to be recognized by teachers as STEM people due to their multiple marginalized identities related to immigrant status, race, and gender. As a result, they saw themselves as outsiders within the formal science classroom space. Similarly, Dawson and her colleagues [31], found that Black secondary school girls in their study in the United Kingdom, had to engage in "good girl student" behavior (i.e., being well behaved) to have their STEM performances recognized by peers and educators. Racism was apparent when Black girls performed the same "laddish" behaviors (e.g., getting messy, shouting, climbing, tinkering) as their white male peers, they were punished for these whereas the boys were not.

These studies in Canada and the United Kingdom highlight how Black students' bids for STEM performance and recognition are often ignored or punished. Similarly, in the U.S., Black students are often viewed through a deficit lens as opposed to an asset-based model in schools [5, 26]. This deficit lens has resulted in the neglect and sometimes abuse of Black youth in U.S. schools, making schooling a space that is not relevant but also not safe [5, 39]. In terms of neglect, research has shown that teachers often define good students as those who are quiet and work hard, labeling bad students as loud or disruptive (e.g., asking questions out of turn) [22, 31]. These mislabeled "bad" students are often ignored or disciplined which can result in them being removed from the classroom during instructional time. As an example of the mistreatment that Black students face in elementary and secondary education settings, statistics show that Black girls are suspended at six times the rate of their white female peers [5]. Darker-skinned Black girls are suspended at a rate three times higher than their lighter skinned peers. Research shows that many teachers and administrators hold racist and sexist stereotypes that cause them to punish Black girls and boys, calling them disruptive and defiant, in different ways than their white peers [5].

To change this deficit narrative and make schools more inviting to Black students, education researchers advocate that teachers need to consider the identities of their students, their relationships with others, their agency, and their positionality in given contexts [34–36]. These identities can include racial and gendered identities as well as STEM identities, and each can affect the development of the others. Researchers advocate the use of culturally responsive pedagogy (CRP) that focuses on the assets that Black students bring to their education, including individual, family, and community knowledge and experiences that can enhance perspective taking and learning, including science learning, for all students [34–37]. CRP has been implemented in classrooms across the US for more than two decades. Despite research supporting CRP, the majority of the elementary and secondary education teaching workforce is white [5], and these individuals struggle with the same racial implicit and explicit biases that the general population experiences [38], which can make it difficult for Black students to see themselves receiving their due respect in these spaces.

Like the international research, U.S. centric research points to the sociocultural portrayals and influences of STEM disciplines that have resulted in its perception as an acultural, ahistorical, apolitical, colorblind, and/or neutral space that negatively impacts Black students [22, 30, 31, 35]. In addition, science and math teachers are often students' first introduction to STEM and often portray it as classroom centric (e.g., students rarely use outside information or their own experiences) and/or a set of rigid rules to be memorized as truth [22, 26–29, 34]. Rigid perspectives of teachers can result in students who resist accepting these 'rules', setting them up to be unjustly labeled as "bad" students and consequently neglected within the science classroom [7, 22, 31]. In addition, science instructional materials are steeped in history and perpetuate narratives about what school science is and how science learning and teaching are done, resulting in the marginalization of those who do not fit the white and male dominant narrative of STEM [35]. This experience negatively affects Black students' ability to feel like they belong or can be successful in STEM – their STEM identity. Seeing how racism impacts Black students' experiences in primary and secondary school, including science/math classes, highlights pertinent issues that affect their motivation to persist and their sense that these disciplines are beneficial to them. To

understand how Black students negotiate STEM and school spaces, we are guided by the STEM identity framework [7, 22, 23]. As such, we are focused on how Black students in our sample see themselves as succeeding and belonging in STEM and how they perceive its relevance, both of which can impact their identification with STEM [22].

Research on CRP in science and math teaching has connected STEM identity as important to helping students see value in STEM and their own contributions to STEM. CRP science and math teaching are guided by the following tenets: (1) improving students' achievement, access, and inclusion in school science by connecting classroom learning to their personal lives to demonstrate relevance [32]; (2) increasing students' interest in and identity with science [36]; (3) broadening what counts as science by making visible how family and home practices fit within the epistemologies of science to push against the privileged forms of science [37]; and (4) exploring the intersection of science with social movements toward social transformation and justice [35, 36]. CRP has asked teachers to reflect on the messages about scientific disciplines that they portray to their students, including who and what counts as legitimate within the sciences, and consider how that might affect students' STEM identity [32, 34, 36, 37].

These cited studies have focused on the role of teachers, with few giving voice to Black youth. Our study fills this gap by empowering Black youth to provide their input on issues affecting them in STEM classes and asking their opinions of what could be done to improve these spaces.

4 Methods

The goal for this study was to understand how Black students in a mid-sized city in the southeastern U.S. view their science and math classes as well as STEM disciplines more broadly. We chose to utilize focus groups to empower participating youth by giving them an opportunity to be part of the change they want to see in their schools. Secondary school students' voices have historically been missing from educational improvement and policy decisions. This study was supported by the local school districts through support from principals at various schools and directors of STEM summer camps that serve majority Black students. Specifically, we were focused on issues affecting Black students' interest and success in science and math classes in our local community. Consequently, this was an exploratory qualitative study driven by the following research questions:

1. How are Black students experiencing STEM in their current schools and classrooms?
2. What could make STEM more relevant, personal, and empowering for Black students?

4.1 Participants

Although we initially tried to conduct focus groups in secondary schools that had a majority Black population of students, it was challenging to schedule a time that worked for the schools before the school year concluded in May of 2023. Consequently, the research team decided to focus on recruiting participants in summer camps instead. During the summer of 2023, the lead author emailed the directors of STEM camp programs at a local predominantly Black university, a center for girls and women that serves low-income families, and a research facility that has multiple middle and high school summer programs that serve low-income students. The directors at each of these organizations shared the invitation with camp teachers who could decide whether they had time in the schedule for the focus group. Teachers were responsible for giving the students the assent forms and collecting the parent consent form and the child assent form. We recruited and met with 115 secondary school students enrolled in summer science camps[2] that predominantly served students of color (~ 60% of our participants were Black and close to half of these participants were girls). Table 2 provides the pseudonym for each camp, the total number of consenting youths participating, and the number of Black students, including gender breakdown. Camp teachers at each camp site provided information on participants' race/ethnicity based on the demographic information collected by the program. We were not able to collect data from all participants related to family income, school attended, or zip code. However, some students would reference their school in their focus group comments. But because we could not collect this from each participant, we cannot provide accurate data here. Students were given a $25 Amazon gift card after the focus group was completed.

[2] We recognize that focusing on science summer camps might bias the results, however, research shows that even science-interested students of color face racism in their science classrooms, so this group has valuable information to provide.

Table 2 Demographics of participating summer camps

	Number of Youth	Number of Black students
Camp 1	13	12 (6 girls, 6 boys)
Camp 2	7	4 (2 girls, 2 boys)
Camp 3	5	4 (2 girls, 2 boys)
Camp 4	9	5 (5 girls)
Camp 5	9	9 (4 girls, 5 boys)
Camp 6	5	4 (3 girls, 1 boy)
Camp 7	3	1 (1 girl)
Camp 8	8	3 (2 girls, 1 boy)
Camp 9	22 (separated into two separate focus groups)	5 (2 girls, 3 boys)
Camp 10	14	14 (5 girls, 9 boys)
Camp 11	20 (separated into two separate focus groups)	8 (8 girls)

4.2 Procedures

All procedures adhered to an approved IRB protocol. We conducted 13 focus group, utilizing a semi-structured interview protocol (Table 3). Group sizes ranged from 3 to 14 participants. Questions were designed to be concise and open-ended to encourage more than one-word responses. Interviews were conducted in person at the summer camp locations. The lead author facilitated all of the focus groups except for one that was facilitated by a graduate research assistant who had listened to the audio files of previous focus groups to prepare. Only one researcher was present for each focus group. Each interview was audio recorded and transcribed. Before conducting the interviews, the authors developed a set of questions which incorporated the STEM identity framework. Table 3 highlights how the interview questions related to our research questions and framework.

During the focus groups, desks or chairs were arranged in a circle with the recording device set up in the center. Focus group interviews ranged from 18 min to one hour and 18 min. The audio recordings were transcribed through an AI web-based service. The research team reviewed these transcripts for accuracy. Transcripts were saved as Word files and any names (e.g., school, teacher) were not included to ensure confidentiality. The authors and one additional research assistant had access to these transcripts, all of whom have taken the required ethical research conduct training.

Table 3 Focus group questions and connections to research

Focus group questions	How it related to research questions and STEM identity
1. What do you get excited about in school? Why? 2. What do you get excited about outside of school? Why?	Purpose of these questions was to determine what activities both inside and outside of school were most *relevant* to youth
3. What do you like about your science and math classes? 4. What do you dislike about your science and math classes? 5. What could make these classes better for you?	Purpose of these questions was to determine what aspects of school STEM classes youth enjoyed (focusing on *sense of belonging* and *relevancy*) and what aspects of STEM they did not enjoy. These questions helped us determine how youth are currently experiencing STEM
6. What do you picture when you picture a scientist?	Purpose of this question was to determine what stereotypes youth held related to STEM and who does STEM to determine how well youth can feel like they *belong*
7. Are there any issues that you are concerned about in your school or community? Why?	Purpose of this question was to determine if STEM could be more relevant to youth (E.g., address concerns in their community)
8. In your opinion, does science and technology benefit you, your family, your community? Why or why not?	Purpose of this question was to determine if STEM was *relevant* to youth (E.g., valuable to them and their families)

4.3 Data analysis

It is important to note that students did not have to respond to any or all of the focus group questions. Hence, it is impossible to accurately quantify the numbers of students for each theme. Rather, the unit of analysis was each focus group, specifically the Black students in that focus group. If at least one-third of the Black students in a given focus group mentioned a theme, we considered it as part of our analysis. The research team analyzed the transcripts after all of the focus groups had been completed, thereby establishing familiarity with the data [41]. Each member of the team reviewed the transcripts individually and shared their thematic analyses in a team meeting. We were focused on the themes that we observed from the data related to (1) positive and negative experiences in school and in STEM classes; (2) suggestions for improvements to these experiences; (3) perception of scientists; and (4) issues of concern and the relevancy of STEM to these concerns.

Based on the initial review, the research team agreed that data saturation had been obtained with 13 focus groups as we did not observe any new findings or themes. The analysis process employed inductive methods for qualitative description and thematic analysis to summarize the data [41]. Through this method, we derived themes and subthemes from the interview data. The research team reached consensus regarding the thematic content of the interview data, which is described in the next section. Note that throughout the results section, rather than provide an exact percentage, we will provide an approximate percentage because some students did not respond to certain questions.

5 Results

Two primary themes emerged from the focus group data: (1) Relevance of STEM: as identified through issues that youth cited as well as the activities that they enjoyed outside of school, in school, and in their science and math classes specifically; and (2) Sense of Belonging (or lack thereof) within STEM: as identified through their perceived stereotypes associated with STEM and their sense of STEM's value to their lives.

5.1 Relevance of STEM

5.1.1 Activities that youth enjoy

To assess what would be relevant to our participants, we started the focus groups by asking what they liked to do outside of school. The majority of youth from each of the focus groups referenced the following: socializing and being with friends and family, engaging in hobbies/sports, sleeping and relaxing (e.g., watching tv, playing on phone, playing video games) as a source of rejuvenation. We then asked what activities the participants liked to do in school. Over half of our participants could list school-related activities that they enjoyed. These included creative and/or group activities (e.g., band, art class, sports, recess, and lunch). These all served as a necessary social break from classroom learning. For example, one Black male participant explained, "everything is draining. So, when you have time to recharge, it's just like you have your quiet space, you know." The participants enjoyed the socialization they could engage in with their friends in these activities. For those who enjoyed sports, they specifically mentioned that they liked learning new skills and competing. All but two of the focus groups had participants that mentioned enjoying hands-on experiments and gamified activities in their science and math classes, without being prompted to discuss these classes. We noted that none of these aspects were explicitly related to race, but they helped us to understand what was relevant to these students.

5.1.2 Positive aspects of science and math classes

Next, we asked the participating youth what aspects of their math and science classes they enjoyed. Close to 100% of I participants mentioned positive aspects like, "hands-on," "relevant" activities including fieldtrips. In all of the focus groups, discussions about positive aspects of science and math class would involve references to teachers. About one-third of the touth explained that they liked it when their teacher made science and math classes fun by using

games. As one Black male youth explained, "games, it's like fun but you're still learning. That would make it better," thereby connecting the fun of games with learning. The majority of students in our focus groups told us that their learning in science and math classes benefitted from teachers who were good at explaining things, patient, and took time to answer questions.

5.1.3 Negative aspects of science and math classes

When students were asked to describe negative aspects of science and math classes, the majority of students again referenced teachers. The majority of the participants that referenced negative aspects of science and math classes were Black students. These youth referenced examples where their teachers refused to explain things. One Black male participant described this as:

> Like when you ever try to ask for help, she's just like, 'oh, you should know this', but if I don't know this, then are you gonna help me or not? But she doesn't, and then when you don't get it and you just don't get it at all, you keep getting it wrong and she just lets you keep on failing it.

Close to half of the participants described this type of treatment from their teachers including teachers telling students they couldn't ask questions or "yelling at them" when they attempted to ask questions. Some students had been called names by their teachers (e.g., "She calls us retarded."). Participating youth explained that this demeaning treatment made them feel "shame", afraid to ask questions, and often led them to outright "hating" these classes.

About one-third of the youth mentioned that their teachers rushed through math and science lessons, resulting in confusion for the students. One Black male participant explained, "I feel like some teachers just don't put the effort into teaching it correctly. Or like, sometimes they'll teach too much and it's like very overwhelming for most students to process and take information in." Or teachers simply showed videos and students felt like they had to learn the information on their own. Over half of the youth complained about disruptive classmates and a lack of classroom management from their teachers. These participants gave examples of teachers not being able to teach because of disruptive classmates which led to the teacher simply ending the lesson and telling the students to read their books or watch a video. The youth saw this as ineffective because everyone was being punished when it was a small group who were disruptive. A majority of participants expressed that these classes would be more enjoyable if they had teachers who showed empathy, took the time to make sure students understood the content, and could be flexible with students different learning styles.

In addition to teachers, just under half of the participants also mentioned that their math and science classes did not engage them enough. They wanted more hands-on activities, including but not limited to labs. They were disappointed that these classes were mainly lecture-based and that the homework felt like busy work rather than an engaging learning activity. Close to one-third of the participants expressed their view that science and math was confusing and hard. When asked whether she liked science or math, one Black girl explained:

> Student: I keep changing my mind, debating on if I like math and science. Currently at this moment it's both, so probably next year I'm gonna probably hate them.
> Interviewer: Why?
> Student: Because most likely they'll be harder

This conversation excerpt highlights how this participant worried that math and science would get harder and affect her enjoyment of it.

5.1.4 Issues of concern

To assess whether STEM was a prominent concern or how it competed with other areas of concerns, the youth were asked what issues they were concerned about in their community and why. Of the 13 focus groups, at least one-third of the participants from each of the groups mentioned safety issues in their schools and communities as major concerns. These safety issues included: fights or bullying in schools (mentioned in 11 focus groups), weapons in schools/fear of school shootings/lockdowns (mentioned in eight focus groups), and drugs (mentioned in 6 focus groups). Examples of bullying included a queer youth who described being bullied in her school:

> [Starting] in fifth grade I called myself asexual because I didn't like anyone. And then my own friend, he got so heated because of like something, like me taking the basketball. They were playing a game and it bounced up to

> the side of the court and I picked it up and they yelled for me to give it back. And I literally said, give me a second. And before I could finish my sentence, he yelled, 'you asexual freak, give it back.'

Other students described examples of bullying that they experienced or witnessed and how this caused anxiety for them.

In response to school shootings, one Black youth expressed the anxiety best through her comment:

> [Fear of school shootings] is like a big thing for me cuz I have really bad anxiety and so like it's really scary for me to go to school and then like think that like somebody can like, walk in with a gun and like kill everyone.

Many students expressed this undercurrent of fear related to the idea of school shootings, a very difficult reality facing school children in the U.S. This was often exacerbated by school lockdowns (i.e., when a school receives a threat and "locks down" the school in preparation for an active shooter event). Multiple students expressed their concern with these reminders of their potential injury or death just by attending school. All of the focus groups mentioned fights in schools, weapons and drugs being brought to schools. These issues along with the fear identified due to threats of school shootings and lockdowns, creates a climate of anxiety for these youth, making it difficult for them to see current or future value related to their classes, including their science and math classes.

At least one-third of youth in nine of the thirteen focus groups also mentioned issues they had with teachers and the quality of their instruction along with the inequity of funding in the district leading to their schools having multiple issues (e.g., closed or dirty bathrooms, bug or rodent problems, lack of resources like advanced placement classes or uniforms for band/sports). And these comments were referenced more by Black students than the non-Black participants. In terms of quality, students described teachers who didn't accommodate their disabilities (e.g., attention deficit and hyperactivity disorder (ADHD)) or who simply ignored them. For example, one Black male youth explained, "my teachers, they don't give me a chance. Like when I try to, like do their work myself they ask, 'why am I always fidgeting' but I can't always stop it. Cause it's like a thing [because of my ADHD]." Another Black male youth described his overall sense that the teachers didn't care about him or his peers:

> It's just like all the teachers care about are their paychecks but you don't care about the students. And I feel like if you don't put more work into your students, you don't know what I could [do]. If y'all were the best teacher ever, I could go tell my auntie and my auntie goes and tells my cousin and my cousin could tell the whole world and they could come here and y'all would be the top school.

This student is expressing the sense of neglect he feels at his school, teachers being more focused on their paychecks than student learning. But at the same time he is advocating for his value. He knows he deserves better from his teachers and if he were to receive a quality education, he, and his family, could recruit more students and continue to advocate for a quality school.

These responses related to teacher quality were connected to school funding. The youth who described poor quality teachers referenced their school's name in their comment – usually because other participants would ask – and these schools were the lowest funded schools in the district. At least a third of focus group members in eight out of 13 groups explicitly referenced the underfunding of their schools as an issue they were concerned about. Often these concerns were expressed through discussions of permanently closed or "disgusting" bathrooms, pest problems, classroom and facility degradation. One Black female youth expressed the lack of resources as it directly applied to her access to quality science instruction.

> Something that I am concerned about, is just how underfunded our school is in comparison to other schools around us. And like how we are lacking a lot of resources that other schools have and like programs. Where's our IB [advanced] program? Like I love that we have this program [this focus group was held at a summer enrichment program at a local STEM facility that serves students from this high school]. I think that's wonderful. But *I think we deserve more*. I think if a little bit more attention and love and money was put into our school and not into [the nearby more affluent school], even though we're the poorer zip code school zoning and it's just, it's really disappointing to see that we have so much potential. But where is it going?

This young woman, like others we interviewed, could describe how their schools and teachers were neglecting them. Yet, they were still able to see and articulate their value and the fact that they deserved more from their education.

Lastly, at least a third of the participants in five out of the 13 focus groups mentioned cultural and societal issues permeating their everyday experiences in school: sexist enforcement of school policies and political polarization.

References to sexism came up when girls discussed dress code enforcement as an issue that they were concerned about. One Black girl explained:

> I also feel like the school dress code could be slightly misogynistic. [another girl: Yeah!]. Because boys can literally wear anything and get away with it, but they're so strict about what girls can and cannot wear. I feel like they could do better with that cause at our, like at my school, boys could get away with anything, fights like anything, but girls, they really can't.

The sense that school is a place where rules are applied differently to different people reinforces – in this case, particularly for girls—inequities and a sense of lowered agency that can impact students' enjoyment of school and classes. It is important to note that these comments were made by Black girls but they did not explicitly reference the racial component of gendered dress codes.

The concept of political polarization infiltrating schools came up in three focus groups. In the U.S., political polarization has become more apparent with the backlash to mask mandates in schools during the Covid pandemic and then in 2022 multiple states began to create anti-Diversity, Equity, and Inclusion laws that banned certain books and content that could make people feel uncomfortable. The students in our focus groups mentioned the impact of the polarization. In one high school focus group, the majority of the students came from the same school and described the racial polarization within their own school due to its structure—it is a predominately low-income school with students of color but it also holds a prestigious college preparatory program that primarily enrolls White and Asian students from middle to high income families. In this focus group, two students discuss the segregation they experienced.

> Student 1 (Asian American girl): I guess our school is like really divided too, from the IB and then the other portion of the school' It's like super divided and when you go to clubs and stuff' it's like a club filled with only IB kids or a club filled with like no IB kids. Because like no one really makes an effort to do that. And then I guess yeah, like all the fighting and stuff.
> Student 2 (Black boy): I get what she's saying. Our school's got predetermined cliques. Like, I don't wanna say racist, but like you go to school, you most likely going hang out with the people in your same like race.

Here these students with two different identities are recognizing how the structure of the school, creates these de facto segregated groups, and foments polarization.

Although we asked the question that precipitated these responses last during the focus groups, we chose to highlight these responses earlier in our results because they show the issues that these youth care about. It is important for us to pause and consider how well students can focus on math and science classes when life and death issues are affecting them on a daily basis.

5.2 Sense of belonging within STEM

It is not surprising that the lack of relevance of STEM as well as many of the youth's negative experiences within their science and math classes (and school in general), led them to question their sense of belonging and/or the value of STEM to their own lives.

5.2.1 Stereotypes associated with STEM

This othering of STEM or feeling like they didn't belong in STEM was evident through responses to the focus group question asking youth what they thought of when they thought of a scientist. The majority of participants in every group mentioned stereotypes: old white men, messy hair, nerdy, lab coat and goggles, mixing chemicals, mad scientists, Albert Einstein, Bill Nye, Walter White, not caring about others. One Black student articulated his sense that scientists were "money hungry" and explained, "Because I feel like they could cure some diseases but they don't want to because they will lose money." This sense that scientists could actually hurt humanity is distressing and not a trait that would attract many of these youth to STEM.

One group of students that attended a camp at a local predominantly Black university engaged in a discussion about the lack of racial diversity in STEM and in science/math education, particularly when they thought about what a scientist looks like.

Student 1 (Black girl): I'd like to see like more diversity [among] scientists and science teachers. I think that's definitely something that needs to happen in the future. I mean like, people of all different backgrounds, races, stuff like that. Instead of just it being like, a white man or a white woman.
Student 2 (Black boy): I ain't never seen no black scientists.
Student 3 (Black boy): I ain't gonna lie, I haven't either.
Student 1 (Black girl): There's like barely any, like if we were to go around and ask like what skin tone is your science teacher. It's most likely gonna be a white person.

Here the Black youth are highlighting that they do not see people who look like them in STEM fields and media, but they also don't see people who look like them in their science and math classes, a reflection of the documented lack of diversity in teacher education [5, 39]. To not have role models in any of these spaces along with the lack of relevancy of STEM to their lives discussed in the previous section shows how difficult it is for these youth to see themselves belonging or wanting to pursue STEM studies.

Some youth acknowledged that these initial thoughts were often stereotypes and that not all scientists fit these perceptions. As one Black young woman explained:

I dunno guys, y'all make these people sound like nerds, but I know some really cool scientists with swag. Like there's this scientist. She came in for my environmental science class and she was an environmental scientist and she was just like very, I 'don't know how to explain the aesthetic, but very earthy. Like had her hair locked up and everything and I thought she looked gorgeous. Anyways, she is in my mind like the coolest type of scientists. Like they have a lot of swag.

Despite some youth having positive conceptions of a scientist, perhaps one that they met, the vast majority spoke of perceptions that rule out many of them from fitting in that are based on gender, race, or simply hurting humanity.

5.2.2 Benefits of STEM

This concept of STEM actually hurting humanity, came up in responses to the final question asked during participants if STEM benefits them. Close to half of participants across the groups expressed positive attitudes about science and technology (e.g., "it makes thing easier", particularly communication, "it benefits people" like air conditioning, and "we can't exist without it"). However, close to one-third of the participants in eight of the groups expressed some ambivalence believing science and technology can be destructive (e.g., nuclear weapons, environmental issues) and believed people spend too much time on their phones. One Black male participant expressed this latter concern best when he said, "with technology comes the internet and there's good stuff on the internet, but there can also be bad stuff on the internet and it just, it's kind of an equal balance, but it's, I think it's a good thing most of the time." Youth expressed that it's not just the "bad" things on the internet but how social media and the internet can make them feel about themselves.

This section highlights how Black youth do not see themselves represented in or valued within STEM. When you add the lack of relevancy that these youth see in terms of how STEM and what they learn in science and math relates to their daily lives, then you can see how difficult it would be for many of these young people to feel like they want to pursue these disciplines. These experiences provide some evidence to explain why the representation of people of color within STEM at all levels (e.g., STEM courses in high school, STEM college majors, and the STEM workforce) remains stagnant.

6 Discussion

Our results show us that close to two-thirds of our participants could see relevance in science and math classes, but the structure of their current science classes is resulting in few of them actually experiencing this relevance. Almost one-third of these Black youth are experiencing neglect and lack of care from their science and math teachers, which aligns with both U.S. and international studies [5, 26–35]. Multiple Black focus group participants referenced the neglect highlighted by Love [5] and Ladson-Billings [34], that they experienced when their science and math teachers simply stop teaching as a punishment to the students who were labeled disruptive. When learning is withheld, the students suffer and are unable to see science and math as relevant but simply a punishment they need to get through [5, 34].

Although not an identity, we had focused on, we found that the negative treatment from teachers was felt and voiced particularly by those Black students who also identified as having ADHD or other disabilities. These students viewed the

name-calling and neglect as directly aimed at their identities, which created an unwelcoming environment that was not conducive to STEM learning. Students with disabilities face additional barriers in STEM courses and career paths, including an ableist view that they are not capable of succeeding in these disciplines. Recent estimates show that only 5% of workers in STEM fields have disabilities [1]. This message from the students' perspectives presents another issue of equity in the development of STEM identity during the school years.

Students in our focus groups were also aware of the broader cultural and systemic issues affecting their experiences in school and STEM. Multiple participants discussed the underfunding of schools that affected their access to advanced level classes or even clean bathrooms. This lack of access to quality education or spaces conducive to learning are part of the broader systemic racism that results from school funding mechanisms and cultural stereotypes in the U.S. [5, 33, 34, 40]. In addition, students expressed their concern with violence in their schools that creates a climate of anxiety for these youth, making it difficult for them to concentrate let alone see current or future value related to their science and math classes.

These challenges are then compounded by the cultural view of who is successful in STEM and deserving of resources [10, 22, 35, 39]. The youth in our focus groups referenced these stereotypes as well. Individuals in every group described scientists by referencing at least one of the following stereotypes: old white men, messy hair, nerdy, lab coat and goggles, mixing chemicals, mad scientists, Albert Einstein, Bill Nye, Walter White, not caring about others [10, 17, 34]. Some of our Black participants specifically called out the fact that they had never met a Black scientist or had a Black science teacher. To not have role models or even see people who look like them represented in STEM can confirm these stereotypes for Black youth [10, 17, 22, 34, 36].

This lack of Black role models and the negative experiences within secondary school science classes can make it very difficult for students to see the relevance of STEM and/or STEM classes to their lives [22, 34, 39]. The lack of connections could be seen in the ambivalence many of the youth expressed when asked if STEM benefited their lives. These students could see value (e.g., cell phones ability to allow people to connect with each other across the globe) but also brought up negative ways in which science and technology influenced them or simply had no effect on their lives. These negative aspects along with unsupportive classes and teachers could create a trend for these youth that allows them to fall out of the STEM pipeline.

And yet, despite all of these issues, the students in our focus groups expressed ways in which they could see themselves belonging in STEM. Specifically, they mentioned activities that could make STEM classes more interesting and relevant, such as social, hands-on, gamified, and creative activities. They also called for science and math teachers to be more empathetic, patient, willing to take the time to answer questions, and good at explaining things. Perspective taking and exercising social and emotional quotients are also paramount to creating a welcoming and supportive STEM environment for Black students [35, 36]. These requests by students sound very much like culturally responsive pedagogy (CRP) for science and math teaching. Students are asking that science be connected to their lives [37]. Many Black communities are enduring chronic medical conditions such as sickle cell and higher infant mortality rates. If teachers could connect Black students with scientists working on breakthroughs in these areas, then the students could see potential role models working on research that benefits them. By connecting with people and research that focuses on issues in their communities, Black students could see that their teachers and schools value their right to live a healthy life and their role in making important breakthroughs in STEM, which could begin to change the dominant narrative of who belongs and succeeds in STEM. In addition, teachers simply showing care and respect would go a long way in helping to reduce students' anxiety that can lead to burnout and feelings of imposter syndrome, which are effects of unwelcoming environments. This care and respect could be demonstrated by making visible how family and home practices fit within the epistemologies of science to push against the privileged forms of science [37] and exploring the intersection of science with social movements toward social transformation and justice [35, 36]. The most amazing finding from this study was that despite the neglect and lack of care that many of our students experienced, they still saw their value and believed that they "deserve more". Consequently, rather than internalizing these negative experiences, many of these youth believed that they had valued and deserved better.

7 Limitations

Although our findings are important to science education research, there are some limitations that warrant consideration. First, our participants were recruited through summer science camps and may not be fully representative of all youth in the broader community. Second, we interviewed students at one point in time, and it is important for future studies to monitor

the evolution of student perspectives on STEM courses and careers over the course of their education. Lastly, students mentioned the influence of other identities (e.g., having a disability, sexuality) that affected their sense of belonging in STEM and school. A future study could utilize an intersectionality lens that could delve into how multiple marginalized identities can affect STEM identity.

8 Conclusion

Despite this study focusing on a small group of youth (~115), the findings can inform pedagogy for science and math teaching. The results of our focus groups provide calls for CRP from Black students [5, 39]. By asking these students about their experiences and recording their suggestions for change, we are not only cultivating their engagement in STEM but showing them their value by seeking their input. Despite the negative experiences our participants described, these students still saw their value to their community and society and believed they deserved better. Which means it is not too late to improve the relevance of science to Black students lives through improved culturally responsive teaching practices in classrooms that link issues facing Black communities to science in the classroom. We recognize that this is just the first step in the much larger task of changing the systems within our society that perpetuate racial differences in society's perceptions of who belongs and can succeed in STEM. However, these students, and many more like them, deserve better and with more equitable science education, they can see their relevance not simply in their imaginations but in their day-to-day experiences with STEM.

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Data availability Data sharing is not applicable to this article as the data collected during and/or analyzed during this study are focus group data and are not publicly available because sharing focus group responses was not included in the consent/assent forms signed by youth and their parents.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Human Subjects Committee of Florida State University (08/10/2022, STUDY00003299). All participants consented to their participation and its use in an eventual publication. Those participants under the age of 18 signed an assent form and their parent/guardian signed a consent form. All participants 18 or older signed a consent form.

Competing interests The authors declare no competing interests.

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