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How do Black engineering and computing doctoral students analyze and appraise their (depleted) STEM diversity programming?

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Purpose: Local and national U.S. programs focused on diversifying science, technology, engineering, and mathematics (STEM) in academia and industry have created academic pathways for Black Engineers. However, most STEM diversity programs in doctoral education typically end or availability significantly decreases. This absence leaves little or limited guidance during the challenging process of completing this terminal degree and seeking employment.

Method: We interviewed 43 Black PhD engineering and computing doctoral students, 37 discussed their experiences receiving equity-minded mentorship in a STEM diversity program, and we asked them about the value and lapsing of this programming.

Results: These doctoral students felt the absence of equity-minded mentoring through culturally affirming diversity programming. Often, funding for these programs has been reduced or eliminated for graduate students. National conferences, sponsored by national societies, partially filled the vacuum, offering equity-minded mentoring that affirmed STEM identities.

Discussion: We propose that doctoral students benefit from institutionally-maintained diversity programs that address racial disparities. These programs could provide mentoring focused on equity and based on a clear comprehension of structural racism in STEM fields. They also offer counter-narratives that challenge the underrepresentation of Black individuals in STEM.

KEYWORDS

STEM education, diversity, DEI programming, Black doctoral students, mentoring, engineering education, computer science education

Introduction

When doctoral students have effective mentorship, they are more likely to graduate and report higher degrees of satisfaction with their academic programs. However, Black students primarily benefit from mentoring that is not colorblind but conscious of the realities of race and other forms of oppression. Race-conscious mentoring is a type of mentoring that explicitly

acknowledges and addresses the role of race and racism in the mentee's experience. Race-conscious mentors are aware of the challenges that mentees of color face and work to provide anti-racist support and guidance in navigating these challenges. They also help mentees to develop intersectional academic and racial identities and to become more effective advocates for themselves and others. Some STEM mentoring programs have diversity and equity as part of their mission and vision but execute these principles poorly.

Generally, mentoring received through STEM diversity programming has proven effective in forming STEM identities for students minoritized in U.S. contexts (e.g., Black/African American, Hispanic/Latinx, and Indigenous; Alston et al., 2017; McGee, 2021). Mentoring can validate STEM students and build upon their strengths, leading to higher matriculation rates at both the undergraduate and graduate levels while preparing students for STEM careers (Maton et al., 2016; Ridgeway et al., 2018; Russell et al., 2018; Burt et al., 2023). Further, mentoring relationships developed during graduate school contributed positively to graduates' academic and cultural socialization; facilitated cultural knowledge and role expectation; and contributed to their visibility within the profession (Karalis Noel et al., 2022a,b).

However, while universities have increased diversity programming for underrepresented STEM students of color, most serve only undergraduate students (Thomas et al., 2007; Wright-Harp and Cole, 2008). Undergraduate diversity programs involve various participant activities, including academic lectures, social gatherings, laboratory assignments, professional development events, brown bag lunches, and trips to national conferences. Such diversity programs tend to cease at the graduate level, often leaving doctoral students to seek and secure resources and mentorship independently (Williams et al., 2018). Thus, this qualitative study explores how Black engineering and computing doctoral students seek and secure resources to supplement race-conscious mentoring unavailable within their departments, given the loss of STEM diversity programming that provided mentorship at the undergraduate level.

Equity-minded mentoring for Black doctoral students

Black doctoral students in STEM need concerted, continual, equity-minded mentoring (Griffin, 2020) and support, such as resources to travel to conferences or consortiums or to help build intentional networks (Griffin et al., 2020). We leverage Griffin (2020) equity-minded model for mentoring to inform our conceptualization of an *equity-minded mentoring theory* for Black STEM graduate students. Equity-minded mentorship is an approach to mentoring that acknowledges how institutions create and sustain racial and gender inequities in STEM spaces. Equity-minded STEM graduate diversity programs foster a sense of belonging, provide racially affirming programming, and meet the specific STEM and racial needs of minoritzed students.

Drawing upon Hund et al. (2018), we define mentorship as the process by which mentees obtain guidance, support, advocacy, and direction in their career and scholarly pursuits. Mentoring theory posits that effective mentorship is critical for career development (Kram, 1988). Effective mentorship is essential for career development and academic success and enrollment in STEM programs using extant research described below that demonstrates this fact. We contextualize this theory in prior studies demonstrating the importance of equity-minded mentorship for Black STEM students (Varty, 2022; Karalis Noel et al., 2022a,b; Rida et al., 2023).

To cultivate equity-mindedness, Wofford (2022) suggests leveraging graduate education to combat oppressive norms in engineering and computing to promote shared equity leadership. Thus, an equity-minded framework allows us to interrogate the mentoring structures that leave Black students under-resourced and sidelined within their STEM programs. Mentoring focused on the unique challenges of underrepresented students in STEM encourages a robust science identity from an equity perspective (Robnett et al., 2018; Byars-Winston and Rogers, 2019; Ortiz et al., 2019). Having a strong science/STEM identity may correlate with the relationship between mentoring and the retention of minoritized students in research-related career paths (Bhatia and Amati, 2010; Ong et al., 2011; Dasgupta and Stout, 2014; Dennehy and Dasgupta, 2017) and STEM fields (Estrada et al., 2011, 2018).

Why Black doctoral students in STEM need diversity programming

Equity-minded mentorship is a race-conscious framework for Black PhD students who experience racially hostile environments and extreme levels of underrepresentation (Griffin, 2020; McGee, 2020; McGee, 2021; American Society for Engineering Education, 2023). Research shows that the growth of racial diversity in STEM fields has stagnated, suggesting that academic departments continue to struggle to recruit and retain Black doctoral students. Black students remain underrepresented in STEM graduate programs, making up 4.8% of all science and engineering graduate programs [National Center for Science and Engineering Statistics (NCSES) The State of U.S. Science and Engineering, 2022]. The historical forces that have shaped differential access to educational, social, political, employment, and other resources and opportunities to advance, are racialized, multifactorial, and complex, but their impact is clear (McGee, 2020). The result of an individualistic, ultracompetitive, White, mostly heterosexual, militaristically grounded, middle- to upper-class, nationalist, able-bodied, biased institutional culture leaves Black and other minoritized people with all types of bruising and even some permanent wounds (McGee, 2016; McGee, 2021).

Black STEM graduate students often experience many discouraging effects of racism, which can make them feel as though they are constantly being scrutinized; they also report feeling that they must work extra hard to prove themselves in STEM spaces (McGee et al., 2019; McGee, 2020; Gámez et al., 2022; Karalis Noel et al., 2022a,b). This racialized, marginalized milieu does not change for Black STEM doctoral students when they enter a PhD program (McGee et al., 2019, 2021). Research has found that Black doctoral students are disproportionately at risk of being under-supported in their programs. They also tend to experience racial isolation (McGee, 2020) and have a more challenging time finding mentors (Ridgeway et al., 2018; McGee, 2021). Black doctoral students receive constant reminders that mostly white STEM leaders and peers position them as underachieving and as not belonging in these fields because they diverge from the stereotypical, Eurocentric image of a scientist (Alston et al., 2017).

McGee et al. (2022) further explored imposter syndrome among Black doctoral students in engineering and computing. They found that imposter syndrome among minoritized people is a misnomer. It is sociological rather than psychological since it is rooted in the structural racism endemic to STEM; the "imposter syndrome" discourse masks and camouflages the relations of power and privilege in STEM fields. But for racism in STEM, the instances of impostor syndrome we explored would no longer exist (McGee, 2020). Racial biases have been found to affect underrepresented graduate students' career-related identities and even deter them from pursuing a career in academia. Black students' awareness of racial discrimination can be the impetus for them to achieve doctoral-level credentials to become that Black STEM faculty member they rarely or never had (McGee et al., 2015). Social supports such as mentorship and career coaching can minimize the negative influences of racialized stereotypes (McGee and Martin, 2011; McClain, 2014; Williams et al., 2017; McGee, 2020). However, it is important to acknowledge the limits to these individual-focused supports since they cannot solve omnipresent structural racism in STEM.

The dearth of STEM programming at the graduate level

A healthy reciprocal relationship between doctoral students and faculty members is key to a successful graduate school experience. However, most studies assume that doctoral mentorship is synonymous with a relationship with a faculty advisor (Holley and Caldwell, 2012; Welton et al., 2015; Karalis Noel et al., 2022a,b). But not all advisors serve as mentors because of the culture of meritocracy within STEM, leading some advisors to fail to recognize how structural racism, classism, and sexism create additional barriers for Black doctoral students (Burt et al., 2019; Bryson and Grunert Kowalske, 2022). The federal government and universities alike have responded to the shortcomings of programming focused on underrepresented students of color in STEM education, launching various diversity initiatives to address them. Some of these initiatives are supported by federal awards from the National Science Foundation, the National Institute of Health, or other government agencies (Byars-Winston and Dahlberg, 2019). However, STEM diversity programming often focuses on the trajectories and retention of undergraduates alone. This is visible on websites such as the Institute for Broadening Participation, which lists grants open for applications where undergraduate opportunities far outnumber those for graduate students. Broader, national-level initiatives generally include federal programs or conference-based initiatives (National Academies of Sciences, Engineering, and Medicine, 2019). Unfortunately, many of these initiatives are relatively short term and may require participants to pay for at least a portion of their travel expenses, placing further burdens on students with limited financial resources.

STEM graduate diversity programming has positively affected the retention and matriculation rate of underrepresented students of color at the graduate level (Maton et al., 2016; Ridgeway et al., 2018). Existing STEM diversity programs vary in their area of focus. Programming may include postbaccalaureate research programs, mentorship, financial aid, summer research programs, or professional development workshops (Whittaker and Montgomery, 2012; Whittington et al., 2017). Through race-conscious and culturally relevant programming, mentoring has been shown to enhance career development and reduce attrition rates for doctoral students of color (Wright-Harp and Cole, 2008; Alston et al., 2017).

One such example of equity-minded mentorship within diversity programming is Maryland's Alliance for Graduate Education and the Professoriate (AGEP) and the AGEP-T program in Texas, both of which focus on equity-minded mentoring (Tull et al., 2015; Institute for Broadening Participation, 2018; Moreira et al., 2019). Part of the mentoring within these programs equips students with the tools they need to network effectively (Moreira et al., 2019). For example, Racial Revolutionary and Inclusive Guidance for Health Throughout STEM (R-RIGHTS) has launched an online race and gender conscious mentoring program on their website R-RIGHTS.org. R-RIGHTS has compiled video presentations by Black engineering and social science scholars offering virtual mentoring for engineering doctoral students, postdoctoral students, and faculty of color. Mentoring videos address the racial components of experiences, such as being a person of color in engineering and navigating hiring, tenure, and promotion as a faculty member. Since much of the audience for these videos is isolated at their respective institutions, the online format is a way to cultivate community within a virtual space.

Another such program is The Meyerhoff Scholars Program (MSP) at the University of Maryland, Baltimore which is a well-known example of an institutional initiative funded privately by a philanthropic family. It was developed to address the underrepresentation of Black men in STEM but has since been broadened to serve other underrepresented groups in STEM and women (University of Maryland, Baltimore County, n.d.). This program aims to broaden participation in STEM in part through mentorship with program staff, faculty, peers, advisors, and area STEM professionals (University of Maryland, Baltimore County, n.d.). A recent study has shown that Black students in the Meyerhoff program are five times more likely to enter a STEM PhD program and 7.5 times more likely to complete their program (Maton et al., 2016).

Mentorship through the doctoral degree remains necessary and has implications for Black doctoral students' persistence in their programs and career decisions (Felder, 2010; Felder and Barker, 2013). Research has shown that the support of mentors helps doctoral students from minoritized groups counter racialized and gendered experiences and race-related stress (McGee and Bentley, 2017; Barthelemy et al., 2020). Black doctoral students in STEM programs already have higher rates of attrition in both education and industry as compared to their white peers; culturally responsive, effective mentoring for these students is therefore vital (Griffith, 2010; Kokkelenberg and Sinha, 2010; Turk-Bicakci and Berger, 2014; Sowell et al., 2015). Despite these facts, underrepresented students in STEM are *less likely* to receive mentorship than their well-represented counterparts (Gayles and Ampaw, 2011; King et al., 2018; McGee, 2021).

However, not only are underrepresented students less likely to receive mentorship in general compared with their well-represented peers but when they are mentored, they are often matched with STEM mentors who espouse meritocracy or colorblindness in their interactions with students (Felder, 2010; Gayles and Ampaw, 2011; Johnson, 2015; King et al., 2018). This is problematic because colorblind, meritocratic approaches to mentoring neglect to understand the multifaceted ways in which structural racism affects

the academic experiences of mentees (Prunuske et al., 2013; McCoy et al., 2015; Brunsma et al., 2017). This lack of acknowledgment leaves Black mentees feeling uncomfortable and unable to trust their mentors (Blake-Beard et al., 2011).

The present study

This paper explores how the loss of STEM diversity programs at the graduate level contributes to the lack of effective race-conscious mentorship. Our research question is: *How do Black engineering and computing doctoral students respond to decreased STEM diversity programming as they transition into and advance through their PhD programs*? We foreground the experiences of Black engineering and computing doctoral students and postdoctoral researchers, highlighting their challenges and the importance of equity-minded mentorship and culturally affirming diversity programming. We were particularly interested in ways in which students may proactively seek equity-minded mentoring themselves and how they effectively utilize organizations or other resources available to support them. The findings of this study can inform the development of effective diversity programs that can better support Black STEM doctoral students and improve their academic preparation.

Materials and methods

Between 2014 and 2017, we conducted in-depth semi-structured interviews and focus groups with 43 Black engineering and computing doctoral students and postdoctoral researchers. We recruited study participants in three ways: (1) by leveraging the principal investigators' professional connections; (2) by contacting administrative leaders at institutions with five or more tenured or tenure-track Black engineering and computing faculty (as of 2012, according to the American Society of Engineering Data Management System); and (3) by recruiting at national engineering and computing conferences.

All participants self-identified as African American or Black; 25 identified as men and 18 as women; collectively, they represented 13 U.S. engineering schools. For this sample, we conducted thirteen one-on-one interviews and seven focus groups with two to six participants ($n = 30$). See Table 2 for participant details. All participants in the focus group interviews attended the same institution and were at various stages in their doctoral studies. We offered participants a $35 stipend for completing the interview.

TABLE 1 Excerpt from interview protocol.

Mentoring interview questions
1. Does your department perform formal or informal mentoring?
2. Do you have mentors in your field?
3. How have these mentors influenced your academic and career decision-making?
a. This person may cite Role Models. In our definition, a role model is someone you have limited contact with. A mentor is someone you have high level contact
4. Do you have any minority graduate programming on your campus? How do you capitalize on opportunities offered by these programs and similar organizations? How so?

The interviews took place at students' universities, a national engineering conference, and by phone. Interviews lasted from 45 min to just over two and a half hours, with a median time of 1.5 h. Focus groups were as short as 1 hour and lasted as long as 2 hours, with a median time of 1.9 h. The researchers audio-recorded the individual interviews and focus groups, which were transcribed verbatim; however, the interview data below has been edited to omit pauses and other sounds. For the focus groups, researchers used field notes to aid the transcription process and to identify the speakers (Groenewald, 2004; Rudestam and Newton, 2014).

The interview protocol asked open-ended questions but allowed for flexibility in developing new ideas (Yin, 1998). We designed the questions in the protocol to stimulate rich accounts of the student's experiences in the program related to mentoring (or lack thereof), racism, sexism, their plans, and their motivation to pursue and persist in their PhD or postdoctoral programs (Table 1). We asked them questions such as (1) What is attractive, if anything, about a tenure track position in engineering? (2) What are your career goals? (3) Do you have mentors in your field? and (4) Do you think you have the same opportunities to succeed as students of other races/ ethnicities? Although all students were asked the same questions, the order of the questions varied depending on the direction and flow of the student's ideas and responses (Patton, 1990).

Data analysis

We took a phenomenological approach to investigating the mentoring experiences of our sample of Black engineering and computing students. This approach to data analysis relies on in-depth interviews and focus groups for data collection and is useful for investigating insider perspectives (Creswell and Poth, 2016; Miles et al., 2018). The analysis team consisted of three professors, a Black woman professor of faculty-research, a Black woman assistant professor of engineering education, a white woman assistant professor of sociology, one Black male PhD in Engineering, and a Black male doctoral student in education.

First, we reviewed all interview transcripts and wrote memos outlining patterns and themes in the data using NVivo, a qualitative analysis software. Miles et al. (2018) describe theme development as a tactic for generating meaning from data, which aligns with our initial inductive approach. We held bimonthly coding meetings to assist with understanding collective and divergent emergent themes. We approached individual annotating and collective meetings to discuss code development, providing rich dialog around the data, coding, and scholarship. As a research team, we used the current extant scholarship to help us understand our data and advance the field on topics unique to this data set to inform Black graduate student STEM mentoring programming efforts. We compared our annotations, discussed emergent themes, and established index codes and code subcategories grounded in the literature on Black graduate student experiences in STEM mentoring programs. The semi-structured nature of the interviews and focus groups did not always ask students about diversity programs explicitly; however, most students brought up mentoring or STEM diversity-related programming, organizations, or conferences during their interviews. The participants' perceptions of mentoring programs were the focus of this open coding analysis

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TABLE 2 Participant list and demographics.

	Participant pseudonym	Institutional pseudonym	Gender	Status	PhD year	Major/Field	Interview or focus group	Coded for diversity program Y/N
1	Abel	WSU2	F	PhD	2	Mechanical Engineering	FG	Y
2	Alex	STU1	M	PhD	6	Biomedical Engineering	FG	Y
3	Ario	STU1	M	PhD	5	Electrical and Computer Engineering	FG	Y
4	Camella	STU1	F	PhD	2	Environmental Engineering	I	Y
5	Candela	ESU1	F	PhD	1	Human-Centered Computing IS	FG	N
6	Carla	MWPU2	F	PhD	4	Chemical and Biological Engineering	FG	Y
7	Cedric	MWPU2	M	PhD	2	Technology and Social Behavior	I	Y
8	Celine	SPU2	F	Post doc	Post doc	Electrical and Computer Engineering	I	Y
9	Chike	SSU1	M	PhD	5	Chemical and Biomolecular Engineering	FG	Y
10	Chinoso	MWPU2	M	PhD	1	Mechanical Engineering	FG	Y
11	Corey	NSU1	M	Post doc	3	Kinesiology	I	Y
12	Craig	SSU1	M	PhD	5	Material Science	FG	N
13	Darrel	WSU2	M	PhD	5	Biomedical Engineering	FG	Y
14	Derek	ESU1	M	PhD	6	Aerospace Engineering	FG	Y
15	Douglas	ESU1	M	PhD	2 M	Electrical Engineering	FG	N
16	Erika	WSU2	F	PhD	8	Mechanical Engineering	FG	Y
17	Evan	MWPU2	M	PhD	1	Computer Science	FG	Y
18	Hector	ESU1	M	PhD	?	?	FG	Y
19	Jazmin	WSU2	F	PhD	3	Electrical Engineering	FG	Y
20	Jimmy	ESU1	M	PhD	6	Aerospace Engineering	FG	Y
21	Jordan	MWPU2	M	PhD	1	Biomedical Engineering	FG	Y
22	Kelley	WSU2	F	PhD	3	Biological and Agricultural Engineering	I	Y
23	Megan	STU1	F	PhD	4	Electrical Computer Engineering	FG	Y
24	Mykisha	STU1	F	PhD	6	Material Science	I	Y
25	Ngozi	STU1	F	PhD	5	Electrical and Computer Engineering	FG	Y
26	Nicole	ESU1	F	PhD	5	Biomedical Engineering	FG	Y
27	Phillip	ESU1	M	PhD	4	Human Science Computing	FG	N
28	Quan	SSU4	M	PhD	3	Computer Engineering	FG	N
29	Rameen	NPU2	M	PhD	1	Computer Science	I	Y
30	Raymond	SSU1	M	PhD	4	Computer Science	FG	Y
31	Richard	SSU1	M	PhD	4	STEM major	FG	N
32	Saleem	SSU4	M	PhD	7	Computer Science	I	Y

(Continued)

TABLE 2 (Continued)

	Participant pseudonym	Institutional pseudonym	Gender	Status	PhD year	Major/Field	Interview or focus group	Coded for diversity program Y/N
33	Samantha	MWPU2	F	PhD	2	Chemical and Biological Engineering	I	Y
34	Samir	SSU4	M	PhD	5	Electrical and Computer Engineering	I	Y
35	Sandy	SSU4	F	PhD	2	Computer Science Education	FG	Y
36	Sharice	SSU4	F	PhD	1	Computer Science Education	FG	Y
37	Sierra	SSU1	F	PhD	2	Material Science	FG	N
38	Tatum	MWPU2	M	PhD	3	Material Science	I	Y
39	Taylor	STU1	F	PhD	1	Operations Research	I	Y
40	Tisha	SSU4	F	PhD	2	Computer Engineering	FG	N
41	Todd	ESU1	M	PhD	3	Mechanical Engineering	FG	N
42	Vernon	ESU1	M	PhD	1	Human-Centered Computing	I	Y
43	Wei	WSU2	M	PhD	6.5	Computer Science	FG	Y

M = Master's Student.

method. We investigated the STEM programs students described, how they described programmatic elements, and the program's impact on their STEM studies, which generated a full-text transcription of 192 pages. We analyzed this text, organizing it based on the type/name of the STEM diversity program; how the program was discussed; any discussion about the lack of available programming; and the discussion of individual mentors who were either a source of support or failed to support the student. Table 3 contains an excerpt of the coding architecture.

Most participants indicated that their doctoral advisors were not their mentors and that the participant's definition of a mentor, based on their previous experiences, included a more personal relationship than they had with their advisors. Respondents who spoke of individual mentors commented on the latter's participation in or support for diversity mentoring programming.

Results

Loss of STEM diversity programming for Black doctoral students

About 50% of the forty-three students in this study discovered no formal graduate-level mentoring program upon entering their STEM doctoral departments. Participants in our study mentioned that there was little communication with graduate students about events or workshops for underrepresented groups and much less about organizations that supported STEM graduate students of color. Further, some participants discussed programming that was previously in place but no longer exists or no longer exists in its original form. Rameen, a first-year computer science doctoral student, detailed the loss of one of these programs:

> In the [undergraduate] computer science program at Northern Private University 2, they had like a mentor pair up between incoming students and existing students… and I chose the only other Black person in the program (laughs). She's actually at the Tapia conference today. I'm actually rooming with her!

Rameen is fortunate because his mentor uses her resources to continue offering support even though the formal mentoring program is no longer active. Similarly, Abel, a second-year mechanical engineering doctoral student, was distraught by the lack of equity-minded mentoring and characterized his department as competitive and cutthroat. He indicated the benefit of having programming that meets the specific needs of minoritized doctoral students by explaining that "having something that's designed or tailored for to help minorities go through the process without being completely broken, at least for a couple of decades, might help to promote Black [faculty]." Abel's quote highlights the tough nature of STEM graduate programs and the need for support specifically designed for Black students at the graduate level.

In its previous form, one institutionally-funded STEM diversity program provided crucial information about optimizing one's doctoral experience and valuable training for the professoriate. However, it no longer exists as the new engineering chairperson did not support continued funding for the program. While interviewees from this institution frequently brought this program up, we chose not to reveal the name of this program to maintain the anonymity of participants. Ario, a fifth-year electrical and computer engineering doctoral student, was not able to take advantage of this programming before the funding stream ran out:

> I wish I could have continued in [this program] or at least something similar. When I came in, that program was towards the

TABLE 3 Excerpt of coding architecture.

STEM Diversity Programming: Participant references program targeted at providing supports to minorized identities within their institution
I. *Participation in STEM Diversity Programming*: Participants talk about Diversity organizations level of influence diversity programming
i. *Federal Programming* – Federally funded national level diversity programming
ii. *Conferences*: Participants reference conferences as a source of diversity programming
iii. *No Diversity Programming at Graduate Level*: Participant described a lack of available programming for them at the graduate level
iv. *Prior Experience with Diversity programming in STEM*: Participant discussed experiences with diversity programming before the graduate level
II. *Benefits of Diversity Programming*
i. *Stress Level Management*: Participants talked about Diversity programming effectiveness on individual stress management while pursuing a PHD as a black student the impact to community belonging
ii. *Skill Development* – impact to personal educational and career development
iii. *Diverse Networking* – reference to connecting with other Black scholars in their field
iv. *Role model* – reference to participant being connected with a mentor or role model
III. *Student Valuation of Diversity Programming*: Participants discuss how diversity does or does not fit into their work life balance
i. *Not enough Diversity programming*: reference to participant wanting more programming than what is available to them

> end of, I guess [its] life cycle, because of funding. And when I applied, there wasn't any funding available. So, I did not experience what my graduate peers did, which I've only heard great things about it, as far as exposure to minority faculties, going to different events for really preparing them for what is expected of them if they choose to [pursue] academia. And I feel that my research did not allow me to have that much exposure to training after I was done in courses.

Ario highlighted the effectiveness of these programs given that they are still discussed after they have ended; further, he can tell that the loss of this program has made a difference in the quality of his academic preparation.

Conversely, some students who did receive the benefits of a diversity program highlight how these programs positively impacted their educational experience. Both Ngozi, a fifth-year electrical and computer engineering doctoral student, and Alex, a sixth-year biomedical engineering doctoral student, described many positive and racially-affirming aspects of the program from which they benefitted briefly. For example, they mentioned professional development panels for engineering faculty that often featured Black faculty. While another program has replaced it, the two are qualitatively different. For example, the new program is a weekend-long event in January. In contrast, the former program offered continuous programming and support throughout the academic year with ample equity-minded mentoring, as well as seminars, conferences, financial assistance, and various on-campus and neighboring campus workshops. Alex, although not a part of the former program, heard it praised for years, and he concludes his interview by detailing the importance of the now-defunct program:

> A lot of people were encouraging me, and even in early age to do this PhD…But no one really understands what it is, and then they get here, and all of that support stops, and there aren't programs like [that one] to educate you on what a) [is the PhD] experience, and b) what it takes to get through and out. So then other opportunities, once you get that esteemed degree, kind of pop up and look more appealing. An earlier understanding of what being a professor actually is, and what you can do with a PhD will encourage more [students] to stay in academia and uplift others to do that as well.

The above quotations from our respondents show the huge impact that these defunct programs had. Alex's comments suggest that such programs are critically necessary at the doctoral level. Participants expressed disappointment at the loss of programs that provided helpful guidance from past Black engineering graduate students and remained vocal about the desire for programming on the graduate level. According to current Black STEM doctoral students and post-docs, the lack of STEM graduate diversity programming has detrimental effects at both the individual and institutional levels.

Proactively building mentorship and fellowship through national conferences

Those who did not have graduate-level STEM programming attended racially or culturally-affirming national conferences (e.g., Tapia; Black Engineer of the Year Award [BEYA] and Conference; Women of Color in STEM Conference) to supplement the lack of sustained equity-minded mentoring. The main rationale for attending these events was the camaraderie and networking among doctoral and faculty STEMers of color and the opportunity to engage in future research and career advancement. Derek, a sixth-year aerospace engineering doctoral student, explains, "I am really drawn to the diverse environment and am tired of presenting at conferences, and I am the only Black person there." Students also praised national conferences sponsored by organizations that value and celebrate differences and typically have dedicated programming for mentoring and teaching minoritized students. Participants explained that the conference's network building and socio-emotional support acknowledge and celebrate their racial and cultural identities.

Black doctoral students also praised organizations with conferences grounded in programming for undergraduates but with a "welcome back" policy for graduate students. The programs that were most pronounced in the data were: the National Society of Black Engineers (NSBE), Louis Stokes Alliances for Minority Participation (LSAMP), Alliances for Graduate Education and the Professoriate (AGEP), and Richard Tapia Celebration of Diversity in Computing Conference (TAPIA). The most prominent of these organizations was NSBE. Derek, for example, recalled his experience meeting with encouraging and supportive Black faculty at a recent NSBE conference:

> We care about keeping you here, retaining you here. We have this data, we understand that this is an issue. We do not want it to just continue to be that way. We want this…our faculty and our group, as a whole, to represent the society as a whole…we want to make sure you have everything that you need.

These racially-affirming STEM conferences served as "healing places," and Black doctoral students continued to participate in them year after year. Saleem, a seventh-year computer science doctoral student, described these types of conferences as "mental soul food."

While generally discussed as affirming spaces for Black engineers, respondents talked about a downside of NSBE: its focus on undergraduates. Jordan, a first-year biomedical engineering doctoral student, concluded, "it's better than nothing." Additionally, some participants felt disconnected from NSBE because of the heavy emphasis on mechanical, electrical, and civil engineering. Jimmy, a sixth-year aerospace engineering doctoral student, explained, "my conclusion is that NSBE, basically a lot of the exposure is in mechanical and civil. Those are the two most populated jobs in engineering." Jimmy highlights that, despite existing spaces targeting Black engineering students, there are still Black STEM students whose needs could be met more closely if mentoring programming were extended to graduates and undergraduates.

Another conference that Black graduate students felt addressed their racial needs was the Tapia conference. Sandy, a second-year computer science education doctoral student, praised this conference:

> I keep coming back to Tapia, mostly because I met a lot of people that just gave me good advice. Like, I met somebody who won an NSF award, and I talked to them about it. And he was really cool and let me see a copy of his application. And I, I applied [to it] since he won one … gives me inspiration.

Sandy believed she won an NSF graduate research postdoctoral fellowship due to this chance meeting at the Tapia conference. This shows that even one-time meetings, with virtual follow-ups and subsequent communications, have led to productive developments in Black students' academic trajectories, demonstrating the powerful impact of making a meaningful connection with a role model, mentor, or peer. Similarly, Samir, a fifth-year electrical and computer engineering doctoral student, formed a start-up company through a peer mentoring event at NSBE, where he and colleagues participated in a fantasy sports league.

Some conferences, like the Grace Hopper conference, were inspiring because of the explicit focus on women and the concentration on women of color at the conference. Erika, an eighth-year mechanical engineering doctoral student, spoke with pride about this inspiring experience:

> Grace Hopper, she was an inspiration. Even like, that was in the 1940s, 1946, she was just a very big inspiration… It's funny how she was a woman but then [in] our field, people feel that women do not belong there… it's a white male world. Meeting other women of color was equally as crucial as learning the history of women in computer science.

The quotations above show how students use conferences to proactively seek diversity programming that offers camaraderie, networking, and racially-affirming experiences. They found people who share their struggles, care about their needs, and want to help them thrive in STEM. Students felt the support and were inspired by it. Attending these conferences can even compensate for the lack of diversity programming as a way to build a community for Black STEM scholars, an essential facet of existing programs. While these quotations demonstrate that interactions at conferences are valuable to students, most admitted that a yearly conference is not an adequate substitute for sustained equity-minded mentoring within their departments. Some participants did not identify these conferences as sources for equity-minded mentoring. Not all students have the resources or ability to travel to conferences, and thus, many miss out on these valuable interactions, highlighting the need for departmental mentoring resources.

Going federal: federally funded STEM doctoral diversity programming

Instead of a lack of in-house (institutionalized) STEM diversity mentoring programming, many students found solace in nationally-funded and operated programs, distinct from the conferences above. These programs usually relied on in-house, grant-funded programming, often with financial support going directly toward student tuition and other expenses. Respondents discussed the programming in which they participated, either through undergraduate recruitment activities that resulted in a graduate fellowship award or through other means that qualified them for these federally-funded programs.

The most frequently mentioned program was the NSF's AGEP. The AGEP program seeks to improve pathways to the professoriate for minoritized doctoral students, postdoctoral fellows, and faculty, especially African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders, in specific STEM disciplines and/or education research fields (Jones, 2014; Tull et al., 2015; Russell et al., 2018; Moreira et al., 2019). This program allowed some students to connect with equity-minded faculty mentors who offered more support than their doctoral advisors. Darrel, a fifth-year biomedical engineering doctoral student, agreed with this sentiment and spoke of a personal contact he had made through his university's AGEP program director:

> Well, I've had the opportunities to interface with him [AGEP director] one on one as well…yes, he's [a] role model, but at the same time he's so present in the student body, so…it's equivalent to sitting with him one on one, because he's so honest when he shares his own stories about graduate school and… having to overcome like various different situations.

These "warm relationships" participants developed with AGEP program advisors were common among students in our sample. Hector, a third-year mechanical engineering doctoral student, further praises AGEP stating, "It's like they are [the AGEP director and staff] extremely available." This was especially important for students who did not have a reliable advisor or departmental mentor. For example, Nicole, a fifth-year biomedical engineering doctoral student, explained, "I personally do not have a mentor like someone I meet with on a regular basis." She continued by describing the trust she feels with these organizational leaders:

> If I have questions or I need to… have questions or I need some help it's something I know I can go to Dr. S or Dr. W… I trust that

> if I was in some type of situation where I needed some advice or some help, that they would have my best interests.

These students highlight the need for a trusted and consistent mentor that the student feels they can access regularly.

Ten of the thirteen doctoral students discussed or mentioned the National GEM Consortium Fellowship Program (GEM), a privately-operated funding and programming organization that includes mentoring programming and support for engineering research. Founded in 1976 at Notre Dame University, the mission of the National GEM Consortium is to enhance the value of the nation's human capital by increasing the participation of underrepresented groups (African Americans, American Indians, and Hispanic Americans) at the master's and doctoral levels in engineering and science. The GEM engineering program offers master's and doctoral fellowships to minoritized students. Fellowships may be used at any participating GEM Member University. Samir discussed a faculty member that was the university liaison for GEM:

> I'm trying to pursue academia, and Dr. L definitely guided me in that direction. I think they have provided more direction on how to get there, how to establish yourself, and how to attempt to maintain stability… following within that path.

Three students discussed LSAMP, a national alliance-based program. The program's theory is based on the Tinto model for student retention. The program's overall goal is to assist universities and colleges in diversifying the nation's STEM workforce by increasing the number of related baccalaureate and graduate degrees awarded to populations historically underrepresented in these disciplines. Erika, an eighth-year mechanical engineering doctoral student, stated, "If you are not a part of those programs, you will not know about all the opportunities, including mentoring. I do not think they advertise outside of the LSAMP program." Participants compared graduate fellowship funding and the opportunities accompanying that funding to being in a grapevine that provided constant access and communication. In contrast, participants outside that program said they were out of the grapevine. This raises the issue of accessibility of such programs for Black students in STEM.

On the downside, four participants mentioned that limited time for mentoring was a drawback of some national-level programming. For example, some students attended programs that tried to fit mentoring, teaching, and research into the schedule over only two or 3 days. After the conference, students returned to their institutions without any follow-up or additional programming. The Sloan Research Fellowships offered one of these boot camp-style mentoring weekends. The Alfred P. Sloan Foundation makes grants primarily to support original research and education related to science, technology, engineering, mathematics, and economics. The Foundation believes that these fields—and the scholars and practitioners who work in them—are chief drivers of the nation's health and prosperity. Darrell, a fifth-year biomedical engineering doctoral student, discussed the limitations of the Sloan Scholars programming:

> "They never meet on campus, but I attended conferences with Erika and Jazmine, and we go to their mentoring conference, and we learn about mentoring and how to get grant funding for like a weekend." Jazmine, a third-year electrical engineering doctoral student, added, "And then we come back [to campus], and we do not do any Sloan Scholar stuff at all."

Thus, while Jazmine and Darrell described having the opportunity to learn about mentoring and grants through the Sloan Scholars program, both make it clear that these programs' benefits are short-lived and unavailable within their institutions, signaling the need for sustained programming efforts throughout the academic year.

Discussion

Our findings revealed the importance of equity-minded mentoring programming focusing on the intersections of race and gender in STEM education. Effective STEM diversity programs were conscious of the students' racial identities and the unique challenges they face, in addition to fostering the development of their technical skills. Moreover, the study's participants used their agency to seek out organizations they identified as supporters of their professional development. These networking efforts allowed them access to other parties that could meet their mentoring needs. These *ad hoc* mentors served as a stopgap to replace the mentoring their advisors did not provide. However, respondents also recounted how their institution's mentoring programs often disappeared after completing their undergraduate education and were no longer available at the doctoral level. Program longevity and availability impacted students' access to support. Students experienced stress when their institution abruptly canceled diversity programming. Black doctoral students frequently expressed their dismay about the loss or lack of these programs since they were an important part of their undergraduate experience.

These students turned to diversity-related conferences and networks to respond to the loss of equity-minded mentoring within STEM diversity programming at the doctoral level. National professional programs, such as NSBE and Academic Research and Leadership (the graduate and faculty arm of NSBE), helped to create disciplinary homes for respondents. Respondents also supplemented their lack of departmental equity-minded mentoring by participating in national-level STEM diversity programs (e.g., Sloan Scholars, AGEP, LSAMP), creating spaces that fostered their professional development and career aspirations. However, several of these programs have become inactive, mainly because of reduced funding, expired grants, or changes in leadership in an academic department. Jones (2014) noticed a similar reduction in diversity programs at the graduate level; also citing unstable funding. Consequently, Black students are left to bridge the gap on their own.

Concerted equity-minded doctoral-level mentorship is vital for Black doctoral students. It assists them in forming strong STEM interest and identities, prevents attrition, and helps students to persist in STEM career paths (Joy et al., 2019). We investigated the resources that Black engineering doctoral students pursued in lieu of other opportunities or because these organizations supported doctoral students of color. Our interviews with forty-three Black doctoral STEM students helped us understand how they created and sought external tools of resistance and healthy resilience to navigate racially-hostile environments and seek appropriate external support. In lieu of programmatic efforts aimed at minoritized graduate students on their campuses, we found that Black students actively sought guidance

through conferences and STEM diversity programs that operated at the national rather than the institutional level. While national-level programs filled a much-needed gap in available mentoring for Black doctoral students, the limited availability proved inadequate for students, both for those who could receive the benefits and those who could not. These programmatic efforts were sometimes able to somewhat compensate for inadequate or unavailable equity-minded mentoring within participants' departments. However, many national-level programs are limited by the short duration of mentorship. Mentorship in these programs is made available to students only in the form of isolated events, which is not as beneficial to students as regularly available and continuing mentorship.

Although the participants showed initiative and agency in seeking national-level programs, most could not access mentorship from these programs within their universities. This points to a need to expand both campus-based and national-level programs. Students sought programming that also provided effective, regular on-site guidance. Furthermore, these national-level programs and conferences were not equally accessible to Black STEM doctoral students with fewer resources or limited cultural capital. Beyond accessibility, some programs are simply not available at the graduate level. Or once thriving programmatic efforts were discontinued due to a lack of funding. This led students to lament the lack of programming and long for the equity-minded mentoring they should have had. These respondents, often informed by past participants in these programs, understood the benefits of mentoring but were disappointed that they were deprived of benefits previously enjoyed by others. They felt unsupported, highlighting the need to (re)instate on-site programs or expand existing undergraduate programming to include graduate students through the doctoral level.

Some students indicated they were part of an organization that provided outside mentorship and guidance. However, most participants found some support and mentorship in national organizations, conferences, and programs which they found through their own predominately Black networks. Students not funded by these programs miss out on many financial debt-minimizing benefits. The role federally-funded diversity programs have played in increasing Black participation in STEM cannot be ignored. Some federal initiatives provided sufficient financial support through national programs, indicating that while beneficial, these initiatives lacked sustained equity-minded mentorship. Still, due to the limited availability of positions within these programs, many Black STEM doctoral students are left to cope with a lack of equity-minded mentorship at both the institutional and the national levels.

Limited graduate-level funding and equity-minded mentoring opportunities leave some Black students with conferences and national organizations as their only options, which this study demonstrates a need for institutional-level interventions. However, conferences often come with additional costs that can be prohibitive for Black doctoral students, reducing the likelihood that these students will receive the support they need. Increasing scholarship funding to access conferences is an investment institution can make to impact the success of Black doctoral students drastically. At the same time, equity-minded mentoring sessions at these conferences can be transformative for Black graduate students. Through micro-mentoring, students can share space, time, and attention with senior underrepresented faculty of color. Students get access to award-winning grant applications, fellowship opportunities, postdoctoral research prospects, and inspirational messages that continue to motivate them long after they return to their educational institutions. These seemingly brief encounters that led to life-changing and career-defining opportunities show the monumental impact and importance of mentoring for Black STEM graduate students. They also demonstrate the lengths to which underrepresented faculty of color will go to provide the support for Black STEM graduate students that their institutions have failed to provide. The power of these organic relationships has also been demonstrated in the literature. Atkins et al. (2020) found that underrepresented STEM students' informal mentoring relationships were preferred and lasted longer than mentoring relationships formed through their institutions. Thus, underrepresented faculty of color go to great lengths to provide support in these micro-mentoring contexts and go above and beyond to nourish these relationships long term.

The discontinuation of equity-minded mentoring programs at the doctoral level, where Black students are underrepresented in engineering and computing departments, left the latter feeling unsupported, as if their academic programs were not invested in their success. However, the impacts of STEM graduate programming go beyond offering support and training to underrepresented students since our study found that these programs also contribute to the overall diversity of the institutions.

Limitations

One limitation of the present study is that it does not provide a comprehensive analysis of all existing STEM diversity programs, but rather we focus on the experiences of Black students in E&C doctoral programs. Further, since this study only examines Black engineering and computing doctoral students, the findings may not be generalizable to other STEM fields, other racial/ethnic groups. Conversely, this study lacks a closer analysis of the intersectional identities of Black participants (e.g., race, gender, class) such as Karalis Noel et al.'s (2022a) work, thus it can only report on the general Black experience of Black E&C students. Lastly this study the study relied on self-reported data, which may be subject to bias. While we attempted to mitigate these biases by creating a safe and supportive environment for the participants it is still possible that the participants may have underreported or overreported certain experiences or behaviors.

Conclusion

What is clear is that national programs that make a targeted effort to recruit and retain Black STEM graduate students work; however, institutions should seek funding to house and support those programs on campus. In place of departmental efforts, Black STEM doctoral students use their agency to seek equity-minded mentorship that fosters a more fulfilling and culturally-affirming doctoral experience. However, with their many challenges, Black STEM doctoral students are left to find their own people, places, and spaces that celebrate and support, not merely tolerate them. In addition,

having a faculty member at the institution provides internal knowledge of the institution to navigate with more efficiency instead of students using a trial-and-error approach. This burden should not fall on the students. Our study shows that educational institutions must create equity-minded mentoring programming, both in-house and outside of the institution's walls, to shelter these students from racial, cultural, gendered, class, and intersecting vulnerabilities accompanying their experiences. While ramping up the institution's ability to get federally-funded programming and fellowships to support Black STEM doctoral students and their minoritized peers, diversity programming at the federal level must not replace individual educational institutions' fundamental racial-justice commitment and the financial support such a commitment requires. Commitments to racial justice, which may include cosmetic changes, such as revised departmental mission and vision statements, must also include structural improvements, including funding for in-house, equity-minded mentorship programs that have made a measurable difference in the lives of Black STEMmers.

Data availability statement

The datasets presented in this article are not readily available because of confidentiality issues. IRB approval does not cover making the data available to others. Requests to access these datasets should be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Vanderbilt University. The studies were conducted in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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