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Examining Black and Latinx STEM graduate students' laboratory rotation experiences and their impact on advisor selection

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Despite being fundamental to graduate education in the sciences, lab rotations are largely unexplored in the academic literature. The purpose of this study is to understand how the laboratory rotation process impacts Black and Latinx STEM graduate students' advisor selection process. Steeped in Critical Race Theory, this study employed a case study approach to explore the experiences of four Black and Latinx STEM graduate students enrolled at Predominantly White Institutions (PWIs). The article highlights that students who participated in lab rotations were able to gain more insights into their advisor's advising style and lab environment before making their decision. Participants felt more comfortable in labs where the advisors provided a hands-on advising style over a hands-off advising style. Ultimately, results indicated that Black and Latinx STEM graduate students benefited from participating in lab rotations prior to selecting their research advisors. This study's findings may help STEM departments, especially those within PWIs, understand the importance of consistently offering lab rotations for Black and Latinx STEM graduates prior to selecting their graduate advisor.

KEYWORDS

STEM, advisor, lab rotation, Black, Latinx, graduate students

Introduction

Historically, People of Color in the United States have faced institutional racism, including limited access to educational and professional opportunities (Gildersleeve et al., 2011). This long standing legacy of racism has significantly and negatively impacted People of Color's participation in Science, Technology, Engineering, and Mathematics (STEM) (Bullock, 2017; Martin, 2019; McGee, 2020). In 2020, Latinx, Black, and American Indian and Alaska Native students collectively earned 43% of associate's degrees, 26% of bachelor's degrees, 24% of master's degrees, and 16% of doctoral degrees in the five broad Science and Engineering fields of study (Burke et al., 2022). The underrepresentation of students of color in STEM graduate programs is a complex and multifaceted issue that arises from a combination of historical, social, economic, and systemic factors (National Academies of Sciences, Engineering, and Medicine, 2016).

One key component of increasing and retaining the number of students of color pursuing STEM graduate degrees is to better support them during their graduate experience. There are many factors that impact Black and Latinx STEM students graduate experience, such as the graduate student's research interest and alignment (Kim and Beier, 2020), the advisor-advisee relationship (Zhao et al., 2007; McCray and Joseph-Richard, 2020; Bryson and Kowalske, 2022; Wilkins-Yel et al., 2023), institutions and departments (Golde, 2005), academic performance and skills (Sinche et al., 2017; Grote et al., 2021), and collaborative research environment (Trujillo et al., 2015). Many Black and Latinx graduate students in STEM cite funding as a significant barrier to their retention and success (Ramirez, 2013). Specifically for STEM students, lab rotations can substantially impact the academic performance and overall experience of a graduate student (Rodriguez et al., 2022).

Some STEM graduate programs, particularly those specializing in the life sciences, chemical sciences, and biomedical sciences, offer lab rotations. In laboratory sciences, researchers have documented how the first year of doctoral programs is characterized by lab rotations—a process in which students navigate short-term placements in several research labs while finding an appropriate match for their training (Hirshfield, 2015; Maher et al., 2019, 2020). Lab rotations are designed to expose graduate students to a variety of research areas, methodologies, and research environments, allowing them to investigate diverse research interests and potential advisors prior to committing to a research lab and advisor (Lee, 2008; Maher et al., 2019). Lab rotations are often scheduled during the first year of a graduate program; however, this may vary based on the structure of the particular department (Lancaster et al., 2022). Lab rotations are a valuable component of many graduate STEM programs, and they offer several significant benefits to both students and academic institutions.

During each lab rotation, graduate students spend a period of time in the lab, gaining hands-on experience with ongoing research projects and connecting with prospective advisors and members of the research group. These lab rotation programs offer several advantages to both students and academic institutions. The following are the primary benefits of lab rotations: exploration of research interests (Wofford and Blaney, 2021), skill development (Cai et al., 2018), networking and collaboration (Maher et al., 2020), fostering independence (Holley, 2006), selecting the right graduate advisor (Blaney et al., 2022), early publication opportunities, and a shorter time to graduate completion.

In STEM graduate programs, lab rotations are beneficial because they provide students with a well-rounded view and ensure that students make educated choices regarding their research focus and mentoring before committing entirely to a certain research subject and advisor for their dissertation work (Hall, 2006). Graduate programs benefit from lab rotations because they provide students with a broad perspective and ensure that they make informed decisions about their research focus and mentor before committing to a specific research project and advisor for their dissertation work (Wofford and Blaney, 2021). This is a great opportunity for STEM programs to promote interdisciplinary research projects and encourage students and universities to both master disciplinary knowledge and think beyond departmental borders (Gardner et al., 2012).

In addition to developing relationships with their multiple potential advisors and research groups, lab rotations enable PhD students to expand their network within the academic community and foster future networking and collaboration (Maher et al., 2020). Many graduate students join graduate programs with a broad research interest, and lab rotations enable them to explore different research areas in order to narrow down to a particular research emphasis that matches their interests and skills (Maher et al., 2019; Du et al., 2021). In some programs such as laboratory-based disciplines, the research lab is shaped by the principal investigator (PI). One of the primary goals of lab rotations is selecting a PI and their lab, which is a critical step for graduate student success. In this process the role of the faculty members is not only advising students but also to be a model for their future professional experience. Rotating through different labs can allow students to get access to the lab to learn from PI, other graduate students and postdocs, peers and also to expand their network of colleagues, as well as to explore different types of research methods and working styles (Maher et al., 2020).

Relationships formed during rotations may lead to important collaboration, mentoring possibilities, and a larger professional network (Joy et al., 2015). According to extant research, one of the most essential aspects of graduate program effectiveness is communication between the advisor and graduate students (Ives and Rowley, 2005; Lee, 2008). Participating in lab rotations exposes students to potential advisors from diverse backgrounds, which is crucial, because having advisors who share similar experiences and backgrounds can help them find the right fit, overcome barriers, and develop academic success (Maher et al., 2019). This enables both the graduate student, the advisor, and graduate program to assess their compatibility in terms of the student's graduate work.

In some graduate programs, graduate students are required to undergo lab rotations regardless of their background. However, these initiatives can be particularly beneficial for students who identify as members of marginalized groups for several reasons. Lab rotations are great opportunities for students of color to increase socialization and be more engaged in various research labs. Lab rotations bring fresh perspectives from students from historically excluded groups who may not have had access to research opportunities during their undergraduate years due to socioeconomic or institutional barriers (Thiry and Laursen, 2011). Furthermore, engaging in lab rotations gives students from historically marginalized groups an opportunity to explore a range of research areas and demonstrate their skills and capabilities in different settings, which may lead to increased representation in disciplines where they have been historically underrepresented. Additionally, each rotation exposes graduate students to diverse cultures and management methods, which can potentially foster the growth of independence, conflict resolution, and collaboration skills (Mendoza-Denton et al., 2017).

Extensive research has been conducted on the effect of the first year of graduate school on women's participation and success in their chosen field (Golde, 1998; Sallee et al., 2011). Maher et al. (2019) found that the "student grapevine" shapes students' information networks in rotations, aligning with previous findings about the role of peer networks as a socialization mechanism (Gardner, 2007). Such a "grapevine" effect refers to the informal

channels by which advanced students communicate advice to earlier-stage doctoral students. However, Maher et al. (2019) also recognized that these channels may open the "door to systemic inequity in information access" (p. 78). In fact, additional research has revealed that students' lab selection procedures vary based on their gender, race/ethnicity, and generational status (Maher et al., 2020), which may have longer-term implications for key experiences like lab mentorship (Burt, 2017). Other literature in chemistry has also explored how women and men differentially experience lab rotations, with women encountering greater competition and work–life balance conflicts than men (Hirshfield, 2015). Lab rotations foster a culture of intellectual curiosity, openness to new ideas, and the ability to collaborate across boundaries. These qualities are crucial for promoting innovation and creativity.

Despite being fundamental to graduate education in the sciences, lab rotations are largely unexplored in the academic literature. Lab rotations are not well understood, regardless of the fact that many doctorate schools consider them a "signature pedagogy" that distinguishes the first year of graduate study (Golde, 2007, page 350). This knowledge gap presents a compelling invitation for researchers and academics to delve into the multifaceted aspects of lab rotations, uncovering their impact on students' skill development, research productivity, and overall academic experience.

Theoretical framework

Ladson-Billings and Tate (1995) posited that Critical Race Theory (CRT) offers a unique lens to analyze the role of race and racism in perpetuating social disparities between dominant and marginalized racial groups. Through the application of CRT, extant research has been able to question, critique, and challenge the manner and methods in which racism, white supremacy, meritocracy, and racist ideologies have shaped and undermined institutional and systemic policies and practices (Harper et al., 2009). Black and Latinx graduate students in STEM, particularly at PWIs, have had to contend with a barrage of toxic and disenfranchising experiences that are likely contemporary manifestations of the historical legacies of racism and white supremacist practices (McGee, 2016; National Academies of Sciences, Engineering, and Medicine, 2023). By employing CRT as a frame in the current work, we explored how these white hegemonic systems in STEM, especially within lab rotations, affect Black and Latinx graduate students. Given that CRT acknowledges the shared historical conditions and collective experiences and standpoints of and for people who have been systematically oppressed (Crenshaw, 2019), it provided a frame to center those often relegated to the margins in STEM.

To further disrupt academic prose in higher education, CRT has several underpinnings that are central to the current study: (a) the concept that a shared group experience exists among marginalized people and that these experiences are unique and different instead of monolithic, (b) counter-stories and the voices of students of color are vital to understanding their differential experiences in higher education, (c) "rejection of a colorblind society," and (d) the necessity of adopting an epistemological lens for transforming higher education as part of a larger social justice agenda.

With these underpinnings in mind, the current study explored Black and Latinx STEM graduate students laboratory rotation experiences and how these experiences influenced the selection of their graduate advisor. The guiding research questions included:

1. How do lab rotations impact the advisor selection process for Black and Latinx STEM graduate students'
2. What are the benefits Black and Latinx STEM graduate students report after participating in Lab Rotations?
3. What are the challenges Black and Latinx STEM graduate students report after participating in lab rotations?

Materials and methods

The work presented here is part of a larger, longitudinal, mixed-methods study focused on identity integration among Black and Latinx STEM and Social, Behavior, and Economic Sciences (SBE) graduate students as they progressed through their doctoral programs (NSF Grant # REDACTED). A multi-site case study approach was utilized to capture a diverse range of experiences (Merriam, 2009). The research sites consisted of three PWIs located in the Midwest region of the United States. Semi-structured interviews, Likert-scale surveys, and social networking surveys were administered over 4 years to collect complete data sets on 30 Black and Latinx STEM or SBE graduate students' experiences, allowing for an in-depth look at students' persistence in their degree programs and transition into their professional communities. For the study described here, we explored the impact of lab rotations on four science graduate students, including how the rotation experience impacted the lab they joined, their perceived success in the program, and the relationship with their advisors with a particular focus on power dynamics and institutional racism. Using CRT, we were able to center our participants' voices to gain a better understanding of the lab rotation experience, their progress toward degree completion, and the relationship with their advisor over time.

Participants

Due to the broader study focusing on STEM and SBE graduate students, purposeful sampling was used to select only graduate students who participated in lab rotations for this paper. Consequently, the participants in the current study consisted of four students enrolled in science doctoral programs at one PWI in the Midwest. Participants self-identified as a Black/African American man, (n = 1), Hispanic/Latinx woman (n = 2), and Hispanic/Latinx man (n = 1). The two Hispanic/Latinx women originated from and completed their undergraduate degrees in Puerto Rico before coming to the continental United States for their graduate degrees. The Hispanic/Latinx man described himself as Mexican American.

Data collection procedures

Upon receiving approval from the PI/second author's Institutional Review Board, the PI/second author recruited doctoral students' from each institution with the assistance of the registrar's offices. The recruitment email was sent to all students who met the selection criteria: That is, they self-identified as not white or self-identified as white Hispanic, first- or second-year graduate student, and enrolled in a STEM or SBE doctoral program (as identified by the PI/second author utilizing the graduate catalog at each institution). Students were invited to complete a pre-survey after consenting to participate. The pre-survey included demographic information, identity scales adapted from Settles (2012) work on scientist identity and identity integration, and relational identity and social support scales adapted from Bouchey and Harter (2005) scales to identify who participants sought support from and what their connection was to each individual. Participants were compensated for their time with a $25 Amazon gift card after completing the survey. The demographic questions allowed participants to select any and all identities that applied to them and to further describe their identities through open-ended responses. Specific questions asked participants for their racial identity and another asked about whether they identified as Hispanic or Latino/a/x. This survey did not force a response nor limit the number of racial identities selected. In addition to allowing multiple selections, an open-response option was included and participants were prompted to provide their own identity names if they did not see theirs listed.

After the survey, participants were given the option to provide their contact information in an unlinked online form to indicate interest in the study's interview portion. All students who expressed interest in participating in the study were contacted, and interviews were scheduled. Over 3 years, each participant completed a total of six individual semi-structured interviews, two interviews per year, that were conducted by one of the five research team members. Participants were compensated with an Amazon gift card for each interview they participated in: $25 for each of the first two interviews, $50 each for the third and fourth interviews, and $100 each for the last two interviews. The increasing gift card value was designed to improve retention over the course of the study.

The semi-structured interviews were scheduled approximately every 6 months over a 3-year period from June 2015 to December 2017. Each interview included different questions, based on where participants were in their programs. For example, the first interview included questions related to how participants chose their advisor and research group. Later interviews included questions about their career plans. Some topics were consistent throughout all six interviews, including central project foci such as scientist identity, relationship with advisor, sense of belonging, and social support networks. Most interviews were conducted in-person, on-campus or near the university campuses at a location of the participants' choosing, by one of five trained researchers. Each researcher followed the same semi-structured interview protocol but probed and asked follow-up questions according to the responses given by the interviewee. Interviews were conducted by video conference if participants were unable to meet in person. The interview length varied depending on how much information was provided, ranging from 30 to 154 min.

Analytic procedures

All interviews were audio-recorded and professionally transcribed. Names and identifying information were anonymized, with pseudonyms replacing participant first names. The second author generated pseudonyms that aligned culturally with participants' given names; for example, a Latinx participant named Javier might have Juan as a pseudonym while a Latinx participant named Michael might have Matthew as a pseudonym. Transcripts were read several times and discussed by the research team prior to codes being created. Codes and definitions were then revised as more data was analyzed and discussed in an iterative process. Codes were generated from the data and were based on emergent themes in the participants' responses, regardless of the prompt or interviewer question (Saldaña, 2013; Miles et al., 2014). To ensure intercoder agreement amongst team members, the codes and definitions were created and revised several times to increase consistent usage and team members engaged in group coding exercises. Pairs of researchers coded all transcripts for their assigned codes, using Dedoose (Talanquer, 2014), a software program for collaboratively managing and coding qualitative data and regularly met to discuss findings.

The work presented here arises from the code "advisor-advisee relationship." As is common in the sciences, there are multiple terms that refer to the research advisor, and participants used the terms mentor, principal investigator (PI), boss, and advisor interchangeably. The first and second authors identified participants who were enrolled in graduate programs that utilized lab rotations as a means for assigning students to research labs. They each reviewed all six transcripts from each participant, noting how they described the lab rotation process for their program, how they selected an advisor and joined a research lab, what their initial impressions were of the lab environment and advisor, how their relationships with labmates and their advisor changed over the course of their graduate program, and their sense of success in their programs. Analysis specifically probed power dynamics between the students and faculty members in the program, specifically advisors they rotated with, their research advisor, the graduate program director, and other key personnel. As each students' experiences were unique in many ways, the first and second authors identified salient details from each participant's story to include in a brief case study and then looked at themes across participants. The first and second authors met regularly to discuss participants' stories and the emerging findings while collaboratively writing.

Findings

The findings are organized into four case studies, one for each participant, and three themes generated from the combined interview data. Each case study provides a detailed description of the participant, including their race, gender identity, program, structure of lab rotation, experience in their lab rotation, rationale for selecting their advisor, and who ultimately held power in the decision on which lab was joined. The themes will highlight the advisor selection process, benefits, and challenges that Black and Latinx STEM graduate students experienced. Theme 1, how the lab rotations impact the advisor-advisee selection process.

Theme 2, benefits from participating in a lab rotation, expectation, lab environments, and research interest exposure. Theme 2, challenges while participating in a lab rotation, limited guidance about navigating lab rotations and how power impacts their lab rotation experience.

Laura

Laura is a Puerto Rican woman in a doctoral program in the chemical sciences. She attended a 4-year public university in Puerto Rico for her undergraduate degree. Her father had a bachelor's degree and her mother completed high school. Her graduate program required her to participate in two lab rotations, each a semester long, prior to selecting her advisor. Since she also participated in a summer opportunity which required her to arrive on campus the summer prior to starting graduate school, she was able to participate in an additional lab rotation. Having the opportunity to have an additional rotation was beneficial because she selected the PI from her third lab rotation as her advisor. Prior to selecting her final rotation, Laura spoke to peers in her department to get some suggestions on labs to consider for her final rotation. When she approached the faculty member she wanted to complete her final rotation with, he encouraged her to speak with students in his lab first and attend a lab meeting. After speaking with members of his lab (one was also a Puerto Rican woman) and attending a lab meeting, Laura decided to rotate in his lab. Laura mentioned she enjoyed rotating in different labs. Participating in lab rotations allowed Laura to see how each advisor worked with their mentees. She performed well during each rotation and received good feedback from each faculty member. In fact, each faculty member invited her to join their lab.

Nicole

Nicole is a Puerto Rican woman in a life sciences doctoral program. She attended a 4-year public university in Puerto Rico for her undergraduate degree. Both her father and mother completed their bachelor's degrees. Her graduate program required her to participate in lab rotations her first year. She had the option to do two full terms with one lab each term or four half terms with one lab every 8 weeks. Nicole did two lab rotations, each for a full semester, and selected her first rotation as an advisor. Initially he told her yes, she could join his lab but after speaking with the second faculty member she rotated with, who Nicole described as "opinionated," he said she could not join his lab. Nicole expressed frustration with trying to find an advisor that was accepting students and had funding to support them. Therefore, she had to complete an additional lab rotation before selecting her advisor, which put her behind compared to other students in her cohort. Prior to selecting her third rotation, Nicole spoke to peers in her department to get some suggestions. Two peers gave positive references about the same advisor, so she approached him about rotating in his lab. She set up a meeting and learned about research projects in his lab, his mentoring approach, and his expectations. He encouraged her to talk to the people from his lab and to attend lab meetings so she was able to see the dynamics between him and the lab. Nicole decided to rotate with him and subsequently selected him as her advisor.

Nathan

Nathan is a Mexican American man in a chemical sciences doctoral program. He attended a 4-year public university for his undergraduate degree. His father completed high school and his mother completed some college. His graduate program required him to participate in three lab rotations, though he completed three rotations and he did not find the right lab for him. He enjoyed rotating in different labs because he was not sure about the research area he was interested in. After his first two rotations, Nathan found that he did not enjoy the research labs he tried and felt stuck because he was expected to join a lab. He did not feel comfortable in the first lab he tried and the second advisor he rotated with was overly hands-on. Nathan expressed the importance of finding a mentor that allowed him to be independent rather than micromanaging him. A postdoc from his first lab rotation told him he could look outside his program for an advisor, which he was not aware was an option, but it led him to his third rotation and the advisor he eventually decided to work with. Initially, he felt his third rotation was a good fit. Nathan's third rotation combined a research topic he enjoyed, a lab environment that felt comfortable, and an advisor who offered flexibility and independence. However, after 6 months in the third lab he said the advisor's mentoring style shifted to a micromanaging approach which led him to leaving the lab.

Seth

Seth is a Black man in a doctoral program in the chemical sciences. He attended a 4-year public university for his undergraduate degree. Both his father and mother completed their bachelor's degrees. His graduate program required him to participate in three lab rotations before selecting an advisor. Given that Seth had taken 2 years off after completing his baccalaureate degree, and before pursuing his graduate degree, these lab rotations allowed him to have a better understanding of his research interest. Additionally, the lab rotations provided him with a review of concepts in chemical sciences and he was able to gain hands-on experience during each rotation. Seth benefited greatly from lab rotations because he did not participate in research opportunities prior graduate school. Seth expressed the importance of identifying a mentor with a hands-off approach. He wanted to be able to be independent and not work with someone looking over his shoulder. Seth described three lab rotations with various labs as "fairly good" yet he expressed his frustration with the limited guidance he was provided with during the lab rotation experience. While participating in the lab rotations, Seth paid attention to the lab environment because it was an important factor to his decision. Especially, because he did not have a relationship with his cohort. Seth was able to select a lab with an advisor who demonstrated a hands-off approach, was conducting interesting research, and a lab environment that he preferred. It is important to note that his relationship with his lab changed as he progressed through his program for the worse.

Theme 1: advisor selection process

Lab rotations allow graduate students to join labs temporarily to get a feel for the advisor's advising style. All four participants discussed the importance of advising style and the type of mentoring relationship they wanted when considering advisors and research labs. Lab rotations allowed the participants to gain a better understanding of which advising style aligned with their personality before making a selection. The two women in this study discussed approachability and openness as an important feature of their relationships with their advisors. For example, when Laura, a Puerto Rican woman in chemical sciences, was asked about her relationship with her advisor she answered,

> The relationship with my advisor is a good one. He is an approachable person. If you want to go and talk with him, you don't need to schedule an appointment. I never have seen him angry. Well, if you are not working, then, he does get irritated, but if you had data that did not work or that is bad and he knows that you have been working, he supports you and tries to help you to see how we can resolve the problem. He is quite approachable. He's really a nice guy.

Having an advisor that was approachable and available was important to Laura. Similarly, when Nicole, a Puerto Rican woman in life sciences, was asked about her relationship with her advisor, she shared,

> It's a real open relationship in that he encourages me to let him know anything that's going on with me, either any issues or any ideas, or just things that I wanna do, anything I want to talk to him about, honestly. And he's very supportive. He tries to understand where I'm coming from. And right now, I think it's great. I can't really say anything bad about it.

During lab rotations, both Laura and Nicole were able to identify that their advisors had approachable, accessible mentoring styles. However, both men in this study desired a different approach. During their lab rotations they wanted to find an advisor that would have a more hands-off approach which would allow them to work independently. Although Nathan, a Mexican American in chemical sciences, was not impressed with his first two rotations, they did allow him to identify the mentoring style that best fits his personality. He shared,

> So, I guess, because I did the total of three rotations, and I think each rotation kind of guided me toward what I wanted in an advisor. So, the first rotation was a research area that I really liked. . .but I think the advisor and the advisor situation in terms of lab manager, dynamics and relationships with people who I would be working with were not a best fit for me. Although I did like the fact that my advisor was more of a hands off person, which allowed me to be independent, which I liked, but it was just the whole her personality was not very fitting . . .. because she has a lot of conflicts with other people in the lab, and as well as the lab manager doesn't get along with other people either, and the lab manager and the PI are best friends, so that doesn't help either.

Similarly, Seth, a Black man in chemical sciences, desired to have an advisor who was also hands-off. Seth described his relationship with his advisor, saying, "It's great. He's helpful, responds well, is nice but still allows you to figure stuff out on your own. He's not over your shoulder. He's there when you need him." Both Seth and Nathan desired a more hands-off approach while Laura and Nicole appreciated having an advisor that was accessible. Although the participants desired various advising approaches; lab rotations were critical in allowing participants to identify mentoring styles that worked for them and to figure out which advisor was the right fit.

Although lab rotations helped participants get a feel for their advisors advising style, the short term rotation did not allow them to develop a relationship and see how they would mesh with the advisor and research group over time. Short-term lab rotations meant everyone was on their "best behavior" and there was excitement and newness that had not yet worn off. For instance, although Laura initially spoke highly of her relationship with her advisor, as she progressed through her program she was very candid about the need to be independent as he would not solve her problems for her and was not someone she went to for help with experiments. She explained, "My advisor, he's a good person. Great person. Sweet person. However, he is not going to resolve anything for you. He's not going to solve your problems." When asked about mentoring interactions and who she went to for help with research, she always talked about the postdoc in the lab. Each interview, when she was asked about who she sought out when she needed help, she answered, "When I need help, in reality I do not go directly to the PI. I go to the postdoc. The PI is like the secondary person." Similarly, Nicole initially talked about how much she liked her advisor, but that feeling started to sour as time went on. During her first interview, she said,

> So, my relationship is limited right now because I've only been with him for a month, but it's a real open relationship in that he encourages me to let him know anything that's going on with me, either any issues or any ideas, or just things that I wanna do—anything I want to talk to him about, honestly. And he's very supportive. He tries to understand where I'm coming from. And right now, I think it's great. I can't really say anything bad about it. But again, I've only been with him a month, and so I've only met with him a handful of times, and I can't really say until I guess I've gone through the ups and downs of working on a thesis project with him.

Describing her relationship with her advisor later in her program she talked about several tense spots in their relationship and how her perspective of him has changed. She said,

> I've realized in these past months that it really has to be my initiative with everything, I can't rely on my PI. He's just not a person I can rely on when it comes to my project, he's too busy, he doesn't really pay much attention to what I'm doing. And, I think I'm kind of finally passed the frustration phase and just now ready to work and get at it.

Like Laura, Nicole also sought out help and advice primarily from a more experienced researcher who was not her advisor; in Nicole's case, she relied heavily on a physician scientist conducting research in her lab. Both women found alternate mentoring relationships when they realized their advisor was not providing the guidance they needed.

Nathan also struggled to identify a lab that was a good fit for him during his first two rotations but felt more comfortable during the third rotation. He shared, "That third rotation was similar in terms of research field and as well as a PI who had a mentoring style that I liked." Initially, he felt his third rotation had an interesting research topic and hands-off advising approach. However, 6 months into the lab his feelings began to change. He shared,

> Yeah and I'm still rotating from like do I really want to be here or not kind of thing? And then she kind of, I felt like she was being more hostile toward me and I didn't know why. And I was like, is it because I'm new or whatever or because she doesn't want me there anymore does she in her words she doesn't feel like I'm committed to being there. Because she says that I should be there 10 h a day every day and that in order to be serious.

Seth always spoke highly of his relationship with his advisor but as time passed he questioned the fairness of the lab. He shared,

> For instance, I've had to fight for my publications. I had to literally write it, throw it on your desk, not throw it, place it on your desk, I had to spearhead the whole issue whereas I've seen many people whose skin do not match mine be handed publications, for lack of a better word, meaning I almost felt no, I did feel like the word publications was a bad word like it shouldn't be my goal. It should be about learning, the breadth of knowledge, and all that and I felt bad saying, I want to publish.

So, not only did Seth's relationship with his advisor change, he highlighted how publication support and opportunities differed based on race. While he had to "fight" for publications, he noticed that others whose skin differed from his own were just "handed publications." It is in this way that the advisor-advisee experience can differ for minoritized students compared to their white counterparts.

All four participants in this study spoke about the importance of the advisor-advisee relationship. The lab rotation allowed them to learn more about the advising style they preferred and gave them an opportunity to experience their advisors' advising style for a short period of time. Unfortunately, the lab rotations were not long enough for them to get a complete understanding of the advisor prior to making a permanent decision. As with all relationships, they changed over time, and for these participants, the relationships became more challenging and tense.

Theme 2: benefits of lab rotations

The participants in this study benefited from participating in lab rotations. They were able to understand expectations, lab environment, and gain exposure to research topics. For example, having clear expectations from their advisor was also important to the participants in this study, which helped them navigate their graduate programs as first generation Black and Latinx college students. For instance, Nicole, a Puerto Rican woman in life sciences, mentioned that she was able to speak with her advisor about expectations during her rotation. She shared,

> We don't have [a mentoring plan] settled, but it's things we have talked about as to what I expect from him and what he expects from me. And so we haven't formally written down a mentoring plan, which we should for some of the scholarships I'm applying to. But yeah, we've kind of talked about those things early on.

For Nicole, having an understanding, although not formalized in writing, of what her lab rotation advisor expected of her was important to her.

Another important factor when selecting a lab was the environment. Seth, a Black man in chemical sciences, shared that the lab environment was an important factor when he selected his advisor. He said, "It was really the atmosphere of the lab and how I worked with the advisor. It was just a good fit." Similarly, Nathan, a Mexican American man in chemical sciences, appreciated being able to experience the lab dynamics during his lab rotations. He recalled not selecting a lab due to the relationship he witnessed between the advisor and others in the lab. He shared that witnessing the climate and culture of the lab contributed to him feeling uncomfortable with the mentoring, lab environment, and research topic, which, in turn, influenced his decision to not select that lab.

Additionally, lab rotations were beneficial because they exposed students to research topics while gaining hands-on experience. This was critical for Nathan and Seth because they both transitioned from an undergraduate degree to a doctoral program and were not exposed to the research experience that many other students had. Participating in the rotations allowed them to gain exposure to various research topics. Nathan, shared,

> I guess, if I had been at Michigan, as a master student, I would've known that, maybe, but coming from an undergrad to a PhD, I guess I was really uninformed as far as what I could do. Because, I guess it's sort of, like a limit in myself, as far as who I get to work for, and it ended up being not really exciting that I ended up doing. So I feel like I wasted half a semester, in a lab I didn't enjoy anyways. So that was a little bit frustrating to me.

Theme 3: challenges with rotations

Participants had little information about the structure of lab rotations and limited guidance on what to look for, what questions to ask, and how to assess fit while completing their rotations. They were also expected to make an important and permanent decision about who they would work with and what research they would work on for their graduate education within a short period of time, making this a high-stakes decision. Although all four participants were at the same university, they were in different STEM programs so their lab rotations were structured differently. The number of

lab rotations, how long students were expected to stay in the lab (8 weeks or full semester), and who they could rotate with all varied. Some departments also allowed students to rotate with labs outside of their departments but did not communicate this information prior to starting the rotation. So, only those who had access to this information were aware that it was an option. Nathan, a Mexican American man in chemical sciences, shared,

> My program expects me to choose a lab that I'll stay in after [the] second laboratory rotation, and after going through both of those labs, I wasn't interested in either one. I wasn't engaged in the work at all, and I found it kind of boring. I didn't like the interpretations you obtained from the results, I didn't agree with the methodology, and it wasn't exciting to me. . .. Initially, I kind of felt like I didn't want to continue anymore because I didn't want to be miserable for 4 years doing something I didn't care about, or wanted to do, or work with a PI who was kind of frustrating, and not a very person-friendly, or somebody to work with. So I felt kind of frustrated, so I was considering just dropping out after the second year, and just accepting the master's degree. But then, when I figured out you can go outside (your program), and I found the lab that I'm really engaged in and I enjoy being in. And I actually like the research, too, and the PI is very nice, and she's a very student-oriented person.

Noteworthy in Nathan's experience is how inequitable access to programmatic information (i.e., being able to complete his lab rotation outside of the department), coupled with two underwhelming lab rotations, could influence Black and Latinx graduate students' intentions to persist in their STEM PhD programs. Similarly, Seth, a Black man in chemical sciences, described experiencing a lack of guidance from his department regarding lab rotations and the classes that would be a better fit while rotating with particular labs. Seth also talked about peers who seemed to know which lab they wanted to join before they started rotations, while he was using the rotations to identify which lab he wanted to join. He explained,

> Because it was just me throwing a dart at a dartboard randomly in picking a class. I didn't know what lab I wanted to join until the rotations were over, but most people seemed [to] know exactly what they wanted to do from day one, which defeats the purpose of the rotation system, I feel. So it would be nice to have higher students or faculty to be like, well, maybe take this course which is very general which could be very helpful no matter where you go or things like that.

Both Seth and Nathan expressed a desire for more guidance on the rotation process, indicating that they felt there was insider knowledge and a hidden curriculum that they did not have access to while other students did. In alignment with Seth's suggestions, equitable access to programmatic information could be improved upon by having faculty and/or more advanced students formally share their recommendations on the classes that would complement specific lab rotations.

Funding was also an important factor when selecting an advisor. Although three of the four participants had a fellowship, it only covered their tuition and stipend for 2 years. Students were expected to join a lab that would cover their educational expenses, find an assistantship, or apply for outside funding. This brought funding to the forefront of their mind while searching for an advisor and added pressure to finish their degrees in a timely manner. Nathan, a Mexican American man in chemical sciences, who completed three rotations and ultimately ended up switching into a fourth lab, expressed being behind on his program milestones when he shared, "I'm technically behind in my preliminary exam because I was supposed to take it in May." Both Nicole and Nathan prolonged the process of joining a lab, which ultimately added pressure to finishing their degrees quickly and secure funding. Nicole shared,

> It's just in the case of the lab, it's not more funding myself, it's more funding the project and so that's when I can't do anything about it until my PI gets grant so that's why the program thinks, feels that I should consider joining a different lab because it's not gonna be anything fixed and something that we don't know when we'll get funded. And so in the long run, it might just end up hurting me more.

Students also felt pressured to select a lab quickly rather than choosing to complete an extra rotation and getting behind. Three out of four graduate students in this study had an additional rotation beyond program requirements. Laura, a Puerto Rican woman in chemical sciences, participated in a fellowship that required her to start the summer before graduate school, allowing her an extra rotation without prolonging her graduate timeline. This was beneficial because she ended up selecting her third rotation. Nicole, a Puerto Rican woman in life sciences, had the option to do two full rotations or four half rotations as part of her program. She selected two full rotations and ended up completing an additional third rotation before she selected her advisor.

Discussion

Steeped in the CRT framework (Crenshaw, 2019), the current study explored Black and Latinx STEM graduate students' laboratory rotation experiences and how these experiences influenced the advisor selection process. CRT was used to foreground the participants' lived experiences and deepen our understanding of the advisor selection process as well as the benefits and challenges of lab rotations. Several CRT underpinnings were central to this study. These included: (a) the concept that a shared group experience exists among marginalized people and that these experiences are simultaneously unique and different instead of monolithic, (b) counter-stories and the voices of students of color are vital to understanding their differential experiences in higher education, (c) "rejection of a colorblind society," and (d) the necessity of adopting an epistemological lens that centers students of color in order to transform higher education. In the subsequent paragraphs, we situate our findings within these underpinnings, the CRT frame, and the existing literature.

Extant scholars have reported that the advisor-advisee relationship is critical to the success and retention of students of color in STEM graduate programs (Bryson et al., 2023;

Wilkins-Yel et al., 2023; Womack et al., 2023). By centering the voices of students of color, a vital component of CRT, this study offered key insights into how lab rotations supported Black and Latinx graduate students in gaining a better understanding of their preferred advising style. Participants in this study repeatedly discussed the importance of identifying an advisor who demonstrated characteristics that aligned with their personalities and work style. Some participants desired an advisor who demonstrated approachability and openness while others preferred advisors who were more hands-off. By participating in lab rotations, Black and Latinx graduate students were better able to identify advisors who matched their preferred advising style.

Lab rotations also served as an avenue to expose Black and Latinx graduate students, particularly those with limited access to prior research opportunities, to different research topics and lab environments. In alignment with past research (Hall, 2006), rotating in different labs provided students with scientific knowledge, exposure to various research topics, and hands-on experience. We also found that exposure to lab environments was a determining factor in selecting a research lab. Participants felt it was important to experience the dynamics of their lab before making a permanent decision. Being able to see how the advisor worked with other students and how students worked together was an important factor in their decision-making.

While lab rotations offered several significant benefits, the challenges they posed illuminated how systemic barriers and disenfranchising practices uniquely affected Black and Latinx STEM graduate students. Although lab rotations were likely designed to level the playing field, the present study found that inequitable access to programmatic information perpetuated disparities. For example, one participant noted that only certain students in his program were aware of the opportunity to complete a lab rotation outside of the department. Being unaware of this information, coupled with two unsatisfactory lab rotations, contributed to this student's decreased intentions to persist in his STEM PhD program. With decades of valiant efforts being made to broaden participation in STEM, practices that perpetuate inequities continue to thwart efforts to achieve a diverse STEM field. Mitigating occurrences whereby only some students, namely white students, have access to insider knowledge and the hidden curriculum will require the creation of systems and structures that streamline the dissemination of information to all students.

A unique aspect of this study is that it not only offered a one-time snapshot of students' experiences in their respective lab rotations, but because of its longitudinal design, was able to explore students' experiences *after* they completed their rotations and through the advisor selection process. This longitudinal qualitative design provided unique insights into how everyone was on their "best behavior," given the short duration of the lab rotations, and how the advisor-advisee relationships evolved over time. So, as students progressed through their programs, they often mentioned experiencing differing advising experiences than the ones that motivated their interest in choosing their respectives labs in the first place. For instance, an advisor who demonstrated a hands-off approach during rotations, switched to a more micro-managing approach as time progressed. Similarly, an advisor who was open and approachable became unsupportive and critical. Notable in one participant's experience was blatant acts of racism whereby he witnessed where students whose "skin [did] not match" his were "handed publications" while he had to "fight for [his] publications." Evidently, the additional layers of race and gender compound power imbalances between students and advisors, where unconscious bias and ingrained attitudes infiltrate every interaction, particularly for cross-race and cross-gender relationships.

Many Black and Latinx graduate students in STEM cite funding as a significant barrier to their retention and success (Griffin et al., 2020). The results of the current study uniquely shed light on how the availability of funding played a key role in the selection of lab rotations and, eventually, a graduate advisor. As a way to counteract the barriers related to funding, students from historically excluded groups are often recruited to graduate programs with fellowships aimed at diversifying the student body, particularly in STEM programs. Despite their attempts at promoting equity, these fellowships are typically for a shorter timeframe than the time that it takes students to complete their STEM degrees. Thus, students are left in a precarious position to find alternate sources of funding. In the current study, we found that Black and Latinx students were concerned with being able to identify a lab that would be able to support them financially when they did not have enough fellowship funding. This was a major concern because students were expected to join a lab that would cover their educational expenses, find an assistantship, or apply for outside funding. General research funding in the lab was a concern as well, since that could stall projects and halt the research they needed to complete their degrees. These findings align with extant research such as Maher et al. (2019) who reported that money underpinned students' rotation options and experiences.

Notably, the power differences between students and prospective advisors also negatively affected Black and Latinx graduate student participants. Power differences often leave students feeling powerless and uncomfortable and this was evident in the current study when students described feeling uncomfortable talking about funding with their PIs. By not having these conversations, participants described feeling like they wasted a lab rotation because their advisor did not have funding to support them. Feelings of powerlessness and discomfort can prohibit students from asking the necessary questions to determine if their potential advisor-advisee relationship would be a good fit for them. It is in this way that rigid hegemonic hierarchical practices in STEM perpetuate stark divides between faculty and students, which perpetuates feelings of powerlessness and prevents students from asking questions pertinent to their degree completion.

Taken together, the findings of the present study contribute to, and extend the literature on, the advisor-advisee relationship through a unique examination of Black and Latinx graduate students' experiences. This study highlights the value of lab rotations while simultaneously shedding light on the ways in which systemic barriers and inequitable practices can negatively affect students' success in STEM.

Limitations

While this study provides new insights into how Black and Latinx STEM graduate students experience lab rotations, it is important to discuss several limitations. We acknowledge that our

sample size is small owing to the limited number of Black and Latinx STEM graduate students enrolled in graduate programs that utilize lab rotations, yet the findings represent common experiences with lab rotations and therefore are likely to be applicable to Black and Latinx graduate students enrolled in PWI institutions across the U.S. Although this study captured lab experiences for Black and Latinx graduate students, the study did not capture the full experience for students. Some students began the study after their first lab rotation, thus the initial interaction with their lab rotation was not discussed in as much detail. A better understanding of the lab rotations could be achieved with a study starting at the beginning of their lab rotation. Additionally, if students were interviewed at the beginning and end of each rotation we would be able to capture a more in depth understanding of their experience. This research was geographically restricted and only conducted in the Midwest, at one institution, which limits the diversity of experiences represented given the overrepresentation of white students at the institutions and in the surrounding communities. While this likely highlights racial disparities and challenges that might not be as pronounced in more diverse locations, it also provides data from locations that have the most need for improvement. The use of robust qualitative data and diverse participant voices, however, lends an authenticity and relatability to the work presented here that is likely useful to both faculty and students within STEM graduate programs across the U.S.

Conclusion

Black and Latinx STEM graduate students benefit from lab rotations because they are able to make a more informed decision regarding their advisor-advisee relationship and what their preferred advising style is, which can help with their overall success in their program. Lab rotations can provide students with a broad perspective and learn about different research areas, lab cultures, and advisors before committing to a specific research project and advisor for their dissertation work. The process is not without its challenges, as our findings illustrate. Graduate students are inherently in a powerless position, as their advisor can dictate their progress toward completing their degree. This is also evident during lab rotations and the advisor selection process, as students try to impress advisors, navigate funding, and find a mentoring relationship that works for them, all with limited guidance. The lack of knowledge regarding the lab rotation and advisor selection process led three out of four participants to participate in an additional rotation before finding a lab to join, delaying their progress in the program.

The keys to improving the lab rotation experience for students include providing a clear and consistent structure for students and faculty, explicitly guiding students through the selection process, and training faculty advisors on implicit bias, mentoring relationships, and communication. The findings from this study highlight the importance of students being aware of and understanding the often unspoken expectations and rules of lab rotations and selecting an advisor. It is critical to provide students with guidance on what to consider before selecting a lab to rotate in, as well as information about who they can rotate with, who is accepting students into their labs, what type of research is happening in the lab, and what funding is available in the lab. While difficult, it is important to do away with rigid hierarchical power differences to ensure that students are comfortable engaging in potentially uncomfortable questions and having hard conversations before committing to a research lab. These suggestions highlight the importance of providing knowledge and access to students, dismantling academic hierarchy, and allowing some of the power to shift from professors toward students.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Western Michigan University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

TB: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review and editing. MK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Software, Validation, Writing – original draft, Writing – review and editing. KW-Y: Conceptualization, Data curation, Formal analysis, Resources, Validation, Writing – review and editing. SA: Formal analysis, Methodology, Resources, Software, Writing – original draft, Writing – review and editing.

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Conflict of interest

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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