

The Role of Culture in STEM Doctoral Mentoring Relationships: A Qualitative Meta-analysis of Student and Faculty Dyad

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While STEM-sourced innovations continue to catalyze social dynamics globally, in the U.S. context, the STEM doctoral programs remain disconnected from racially and ethnically minoritized (REM) populations. REM doctoral students and faculty are almost destined to encounter cross-cultural interactions due to underrepresentation. This qualitative meta-analysis study, based on multiple embedded case studies, explores the dynamics of cross-cultural doctoral mentorship practices in STEM fields from both student and faculty perspectives. Findings reveal that racially minoritized doctoral students often feel neglected and encounter bias, while most STEM faculty lack formal mentoring training, relying on trial and error without cross-cultural awareness. In response, the researchers discussed the need for faculty development programs to foster “culturally liberative mentoring” practices that support students’ diverse needs.

Keywords: STEM doctorale,ducation, mentoring relationships, cross-cultural education

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Introduction

Careers and innovations in STEM (Science, Technology, Engineering, and Mathematics) fields are becoming increasingly popular and globalized. Within this global context, STEM doctoral programs play a fundamental role not only in scientific discovery but also in training the next generation of STEM faculty. In this regard, mentoring is a critical component of doctoral education in STEM, where research training and professional development are integral to academic and industry success. According to the literature, effective doctoral mentoring should support students’ adjustment to the department, advance students’ research and academic skills, expand their networks, and ultimately pave the way for employment opportunities following graduation (Byars-Winston & Dahlberg, 2019; Davidson & Foster-Johnson, 2001; Merriweather et al., 2022).

The U.S. has become an increasingly international context in STEM doctoral education, with approximately 41% of the student body being international, nationwide. However, racially and ethnically minoritized (REM) populations

who are U.S. citizens represent only a fraction, 11%, of the full-time doctoral enrollment in STEM fields (NCSES, 2023). Similarly, faculty numbers in STEM fields follow a pattern with 55% White, 30% Asian, and 15% Black, Hispanic, and other/unreported backgrounds (ASEE, 2023). In this study, REM students and faculty are identified according to the National Science Foundation (NSF)—Alliances for Graduate Education and the Professoriate (AGEP), which involves populations of African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders (NSF, n.d.). In light of these numbers, cross-cultural interactions are inevitable among STEM doctoral students and faculty, especially for the REM student groups. While these relationships offer opportunities for diverse perspectives and innovative problem-solving, they also present unique challenges, including communication barriers, differing academic expectations, and cultural conflicts, which stem from implicit and explicit biases (Byars-Winston & Dahlberg, 2019; Davidson & Foster-Johnson, 2001; McGee, 2016). How do the STEM faculty and REM doctoral students perceive and navigate mentoring

relationships when they lack representation of similar backgrounds? Conducting a meta-analysis of selected reports based on a multiple-embedded case study, this paper examines the dynamics of cross-cultural STEM doctoral mentoring, exploring both student and faculty perspectives, and proposes strategies to enhance the effectiveness of mentoring with the following research questions:

- How do STEM faculty members perceive cross-cultural doctoral mentoring relationships?
- How do racially and ethnically minoritized STEM doctoral students perceive cross-cultural doctoral mentoring relationships?
- What are the commonalities and differences between student and faculty perceptions?

Cross-Cultural Doctoral Mentoring in the STEM Scene

Mentoring literature encompasses various evolving definitions and approaches, ranging from more traditional and unidirectional apprenticeship models to more collegial models that emphasize collaboration, commitment, and mutual agreements to achieve both the mentor's and mentee's goals. In fact, this collegial model led to a conceptual shift from "mentorship" to "mentoring relationships," highlighting the dyadic nature of mentoring (Allen & Eby, 2008; Byars-Winston & Dahlberg, 2019; Eby et al., 2013; Higgins & Kram, 2001; McGee, 2016; Ragins, 2009; Sudha & Rao, 2016).

A range of various factors determine dynamics in any mentor-mentee dyad, such as years of experience, age, gender, and race/ethnicity. Relevant literature indicates that cross-cultural mentoring adds an additional layer of complexity, influencing communication styles, expectations, and perceptions of authority (Allen & Eby, 2008; Byars-Winston & Dahlberg, 2019; Byars-Winston & Rogers, 2019; Davidson & Foster-Johnson, 2001; Hofstede, 2001). While effective doctoral mentorship is a widely recognized predictor of student success, numerous studies highlight that REM students often face distinct challenges in their mentoring relationships, including feelings of isolation, cultural adjustment difficulties, and a lack of tailored support structures compared to their white peers (Gibbs et al., 2016; Kim, 2017; McGee & Martin, 2011; Nettles & Millett, 2006).

Research findings underscore that REM STEM doctoral students are likely to perceive explicit/implicit biases, neglect of their social identities, deficit-based approaches that prevent achieving their potential, particularly from faculty who do not share similar backgrounds (Gibbs et al., 2014). This issue compounds with the underrepresentation of REM faculty in STEM fields, limiting opportunities for students to find mentors who share similar cultural backgrounds or lived experiences, which may eventually

cause self-doubt and attrition (Byars-Winston & Dahlberg, 2019; Ong et al., 2018; Sue et al., 2009). Despite the growing body of work on cross-cultural mentorship, gaps remain in understanding how these relationships function specifically within STEM disciplines, especially from the faculty perspective. The lack of diversity in STEM academia, coupled with the intense demands of research, could lead to cultural tensions between faculty and students (Byars-Winston & Rogers, 2019). From this perspective, this meta-analytic study aims to contribute to the literature by providing both student and faculty perceptions to bring more comprehensive implications for the cross-cultural doctoral mentoring context.

Theoretical Framework

To a larger extent, this study uses bioecological theory (Bronfenbrenner & Morris, 2007), considering human development and learning in an interactive, social, contextual, and holistic way instead of in isolation. Bronfenbrenner's Person-Process-Context-Time (PPCT) model sheds light on the ways to understand cross-cultural STEM doctoral mentoring from both faculty and student perspectives. The person component highlights individual attributes such as a mentee's or mentor's cultural background, values, attitudes, and prior experiences that influence how they engage in the mentoring relationship. Processes refer to the recurring, reciprocal interactions between mentors and mentees, such as feedback, collaboration, and communication, driving development over time. Context encompasses the multiple ecological systems, from the immediate lab environment (microsystem) to institutional structures, funding agencies, and societal norms (macrosystem), that shape mentoring practices and expectations. Finally, the time component of this model captures both the developmental timeline of the mentee/mentor's academic journey and the broader sociohistorical context, including evolving norms and policies around diversity and inclusion in STEM. Together, these elements underscore the complexity of effective mentoring in cross-cultural doctoral settings and the need for culturally responsive, developmentally compatible practices.

Along with the holistic developmental approach of the PPCT model, cultural mismatch theory (CMT) and social capital theory (SCT) provide a more specific perspective for this study, explaining cross-cultural doctoral mentoring relationships. While CMT explains how systemic inequalities and forced norms in the U.S. higher education system could impact minoritized and marginalized populations (Stephens & Townsend, 2015), SCT emphasizes the importance of social networks and managing co-existence in

organizational settings (Claridge, 2018; Coleman, 1988).

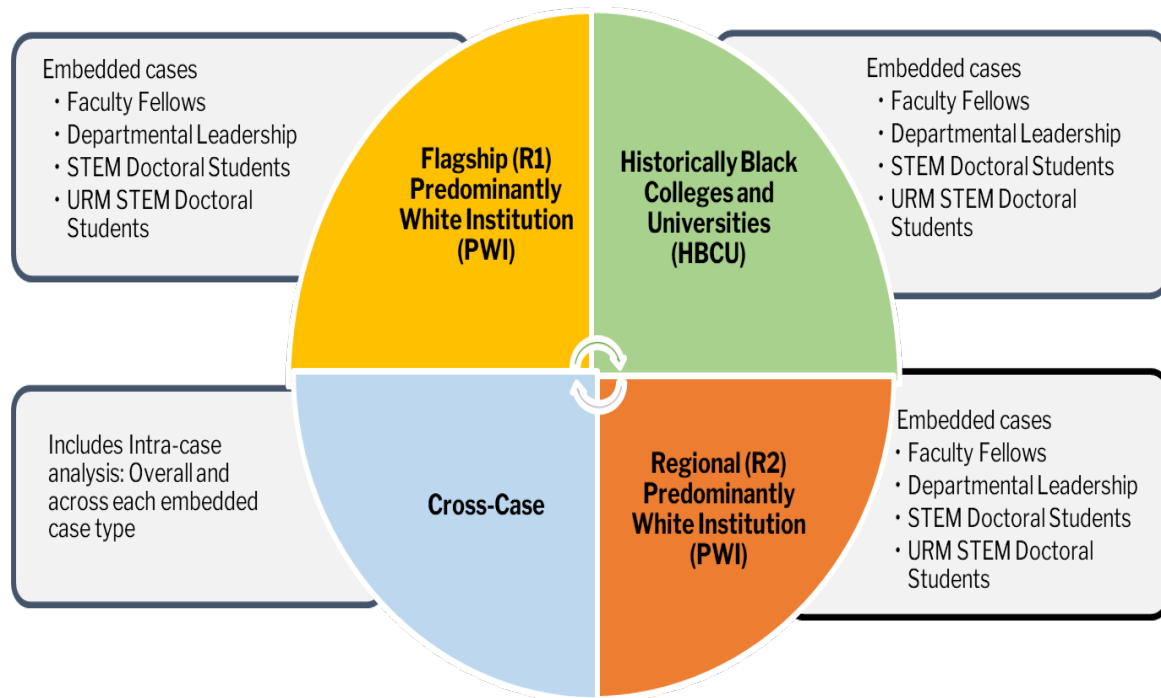
US STEM institutions often structure organizational norms and culture, reflecting the dominant groups—White, Caucasian, and cultural mismatch theory suggests that inequality arises when the dominant cultural norms of institutions differ from those of underrepresented groups (Davidson & Foster-Johnson, 2001; Ong et al., 2017; Stephens & Townsend, 2015). REM groups tend to experience cultural mismatch when they enter these mainstream institutions, where they lack relatability, power, and certainty. When cultural mismatch becomes a hindering factor for success, social capital becomes even more important for REM doctoral student populations in STEM fields. Social capital theory (SCT) describes humans as social organisms that thrive with access to social networks and connections, characterized by empathy, generosity, and cooperation (Claridge, 2018; Coleman, 1988). Acknowledging the importance of coexistence, social capital explains how social context could yield beneficial or productive outcomes. Within this study context, faculty mentors are described as the potential social capital for their doctoral

students by providing them with mentorship support, guidance, collaboration opportunities, and resources to excel in the STEM society. By integrating these theoretical perspectives, this study aims to understand the benefits and challenges of building bridges between students and faculty by welcoming diverse cultural backgrounds. Applying this framework helps in understanding the ways that optimize mutual understanding, academic success, and professional growth in STEM doctoral programs.

Methodology

This qualitative meta-analysis study is based on a list of studies derived from a multiple embedded case study conducted at three public universities in the Southeastern region of the U.S. from 2018 to 2025. This larger study was an Alliance for Graduate Education and Professoriate (AGEP), funded by the NSF. In this study, researchers collected data from three institutions, administering surveys and conducting interviews with STEM doctoral students and faculty members to explore their experiences and perceptions regarding cross-cultural doctoral mentoring relationships (see Figure 1).

Figure 1.
Qualitative Multiple Embedded Case Study



In total, the larger study conducted 104 interviews: the individual interview sample consisted of 49 faculty members and 36

students, and 19 focus group interviews captured 89 students' experiences, averaging 5 students per interview (see Table 1).

Table 1:
Sample Characteristics in the Qualitative Multiple Embedded Case Study

Individual Student Interviews		Student Focus Groups		Individual Faculty Interviews	
Institution Type		Institution Type		Institution Type	
PWIS Regional	5	PWIS Regional	15	PWIS Regional	12
PWIS Flagship	21	PWIS Flagship	55	PWIS Flagship	26
HBCU	10	HBCU	19	HBCU	11
Race/Ethnicity		Demographic Group		Race/Ethnicity	
Black/African American	24	AGEP	32	White	28
Latine	7	Non-AGEP	36	Asian	11
Mixed and Other	5	International	20	Black/African American	4
				Latine	3
				Other	2
Gender		Gender		Gender	
Male	13	Male	48	Male	36
Female	23	Female	41	Female	13
1 st Generation		1 st Generation		Origin	
Yes	16	Yes	24	US	26
No	18	No	61	Outside US	22
Unknown	2	Unknown	4	Unknown	1
Total	36	Total	89	Total	49

Qualitative Meta-Analysis

Conducting a qualitative meta-analysis involves a comparative analysis of primary studies to identify similarities and differences across the studies, thereby emerging a new, authentic interpretation, description, or model about a certain phenomenon (Paterson et al., 2001). In this study, researchers aimed to conduct a meta-analysis to explain the cross-cultural doctoral mentoring relationships in the STEM context with the mentor-mentee dyadic model.

Data Collection and Analysis

The data collection process for this study involved a purposive sampling of primary research reports from the AGEF project, published between 2021 and 2025. Among 16 full-text reports, we selected 9 for this meta-analysis, ensuring a robust representation of faculty and student perspectives, capturing the complete timeline of the project. Each report in this sample captured either faculty or student perspectives, focusing on different groups, including women, black, Latine, Historically Black College and University (HBCU), international faculty, and faculty who work in departmental leadership (see Table 2).

Table 2.
Meta-analysis sample

#	Authors	Year	Interview Sample ^a
1	Douglas et al.	2021	Faculty leadership (n=9)
2	Sanczyk et al.	2021 (a)	Cross-case students (n=29 for focus groups; n=9 individual)
3	Sanczyk et al.	2021 (b)	AGEP faculty fellows (n=6)
4	Howell et al.	2021	Cross-case faculty (n=18)
5	Merriweather et al.	2022	International faculty (n=18)
6	Lambert et al.	2023	Black students (n=9) and HBCU faculty (n=8)
7	Lambert et al.	2024	Women students (n=19)
8	Yaya-Bryson et al.	2024	Cross-case faculty (n=9)
9	Yaya-Bryson & Merriweather	2025	Latine students (n=7)

^aThis meta-analysis is solely based on the interview findings of the listed reports. Survey-based findings were not included in this study.

The researchers utilized NVivo 14 to conduct inductive content analysis on the sample of reports, exploring patterns of specific words and themes that describe student and faculty perspectives. This approach allowed the analysis to occur without a predefined coding scheme, enabling researchers to minimize subjectivity and cultivate a deeper understanding from the project's outputs, which spanned almost a decade.

Positionalities

The lead author of this study is a researcher and woman of Western Asia descent who worked on this project for two years, and the second author, a professor of adult education and Principal Investigator since the beginning of this project, who identifies as an African American woman. Both authors are conscious of how the time they invested in this project and their intersecting identities--particularly related to gender, race, and ethnicity influence their perspectives and interpretations throughout the research process. This awareness was actively integrated into each stage of the study, with intentional self-reflexivity and interactions to ensure they report participant experiences authentically and interpret the findings with theoretical triangulation and literature support.

Findings

The meta-analysis of nine different qualitative studies revealed three main themes. The first theme, "clashing expectations," explains the strong emphasis on science, research, and matriculation, which often glosses over human attributes in STEM doctoral mentoring dynamics. The second theme underlines the consequences of representation issues as the crux of the STEM culture, and the final theme compiles strategies for repowering cross-cultural STEM doctoral mentoring practices.

Theme 1: Clashing Expectations: Hegemonic Normativity vs. Humanity

The results from the content analysis revealed a primary theme that explains one of the prominent notions in STEM doctoral programs: the emphasis on science rather than humanity. Most of the faculty members approach their career and mentoring experiences from a perspective that trumps science over culture. In other words, in their worldview, science has a universal culture, which consists of conducting research and creating scientists. In this hegemonic normative approach, faculty adopt a mentoring style that solely embraces lab work and provides academic support toward graduation and suggest human-related cultural factors such as race, ethnicity,

and gender are independent from the culture of science (Douglas et al., 2021; Howel et al., 2021; Lambert et al., 2023; Merriweather et al., 2022). In Sanczyk et al (2021b) study, one of the faculty members stated: "As a mentor, you're guiding them down a scientific path. You do not necessarily have to explore other things in their life that can be more challenging."

In fact, both students and faculty experienced role ambiguity when asked to define their mentoring experiences. Faculty perceived mentoring as a synonym for academic advising, and students were reluctant to label this mostly academic support as mentoring (Howell et al., 2021; Sanczyk et al., 2021a, 2021b).

The faculty tend to concentrate their expectations on their students to succeed in the program to meet graduation requirements, focus on research as employees of their lab, and get the work done to serve the faculty's research agenda. Douglas and colleagues (2021) stated that this mentoring style "leaves little room for building a healthy mentorship, which can lead to almost no room for culturally centered mentoring since the assumption is that training one on how to "do science" is all that is needed in the process of developing students as scientists." Merriweather and colleagues (2022) also highlighted the assimilation process of international faculty within the dominant STEM culture with the following statement:

The emphasis on pragmatics and universalism of STEM was not unlike what we have uncovered in the larger case study, in which the majority of faculty were White and men, marking the perceptions of international faculty as not much different than their majority White faculty peers. This hegemonic normativity was also demonstrated in how the majority characterized culture.

On the student end, the faculty's positioning on the pragmatic mentoring expectations was correctly received. Most of the findings from student data indicated that their mentoring relationships are strictly work-related and benefit the faculty, rather than having a reciprocal agenda (Sanczyk et al., 2021a; Yaya-Bryson & Merriweather, 2025). One student commented on how their faculty was focused on matriculation and academic advising more than any other aspect of mentoring:

In terms of advising, she's been great helping me move forward in the program. It's absolutely wonderful. When it comes down to the mentor and thinking about it this way, I would say that I don't have a mentor at this point. (Sanczyk et al., 2021a).

REM students remarked that they seek reciprocal respect, communication, learning professionalism, and potentially a long-term collegial relationship with their mentor (Lambert et al., 2024; Sanczyk et al., 2021a; Yaya-Bryson & Merriweather, 2025). One student discussed the importance of

developing a mentor-mentee connection, saying, I think being able to establish a connection outside of just science is important. He or she just doesn't have much of a connection; I don't really have that one-on-one connection with her or opportunity to talk to her. (Sanczyk et al., 2021a) On the contrary, a woman student participant in Lambert and colleagues' (2024) study shared their positive experiences with a faculty mentor: she's (their mentor) very invested in my success as far as not only doing the research that is for her, but finding a career that I'm happy with and that I can have the type of lifestyle that I have, and helping me to reach all of those goals.

Overall, while the majority of the faculty were likely to follow a pragmatic and normative mentoring approach, students desired more humanistic encounters with their mentors, ensuring sustained communication (Douglas et al., 201; Lambert et al., 2024; Merriweather et al., 2022; Sanczyk et al., 2021a; Yaya-Bryson et al., 2024; Yaya-Bryson and Merriweather, 2025).

Theme 2: The Crux of the STEM Culture: Representation

One of the major themes that emerged from the meta-analysis unpacked the crux of the above-mentioned clashing expectations and described representation issues from both student and faculty perspectives. Parallel to national statistics, representation in STEM fields remains homogeneous, consisting mostly of male and white individuals (NCES, n.d.; NCSES, 2023; NSF, 2023). The findings show that in most STEM departments, international student recruitment serves as a means to ensure diversity, and faculty are more likely to approach international students from a "cross-cultural" mentoring perspective, rather than domestic minority students (Howell et al., 2021; Lambert et al., 2023; Merriweather et al., 2022a; Yaya-Bryson et al., 2024). For instance, an Asian faculty member stated (Merriweather et al., 2022):

A lot of the STEM discipline graduate students are foreigners from other countries, they're not from the US, right? [...] When they talk about diversity, and I've gone to some of the workshops, I know it is all about the minorities, which are U.S. citizens over here. But our big problem in STEM disciplines, I can tell you, is not just that, it is also cultural from foreign countries.

On the other hand, underrepresentation of domestic minority students in STEM appears in multiple forms, often involving racially and ethnically minoritized (REM) status, which frequently overlaps with being a first-generation student. Among these groups, women students

have particularly voiced concerns about the absence of culturally responsive doctoral mentoring experiences. The meta-analysis findings indicate that REM, first-generation, and women students are more likely to experience isolation, intimidation, and a lack of relatability and belonging. These experiences are also accompanied by adverse perceptions such as exclusion, implicit bias, and a lack of self-esteem (Lambert et al., 2023; Lambert et al., 2024; Sanczyk et al., 2021a; Yaya-Bryson & Merriweather, 2025).

Catch-22: Can the illusion of sameness veil implicit biases?

Students' perceptions of implicit bias clearly echoed adverse faculty presumptions that were raised in the faculty interviews. Study findings were in consensus about STEM faculty members' color-blind and deficit-based presumptions and negligence when they work with REM students. One of the most prominent approaches that faculty adopt is to treat all students the same way, instead of an individualized approach, regardless of student background (Douglas et al., 2021; Howell et al., 2021; Lambert et al., 2023; Merriweather et al., 2022; Sanczyk et al., 2021b; Yaya-Bryson et al., 2024). This "ideology of sameness" approach is rooted in a few factors, and the most frequently mentioned ones are the faculty's demographics and the inherited attitudes from their former personal and professional experiences (Douglas et al., 2021). Several studies described these attitudes as a subliminal mentoring journey, in which faculty members follow a path that was gifted from their former doctoral mentors along with their familial/contextual upbringing, resulting in a trial-and-error method, without allowing deep connections, empathy, and self-assessments of their own dispositions and attitudes (Howell et al., 2021; Lambert et al., 2023; Merriweather et al., 2022; Sanczyk et al., 2021b; Yaya-Bryson et al., 2024). For instance, one faculty member explained how they model their former doctoral mentor, saying "that is what my mentor did and that's what I would like to do" (Merriweather et al., 2022). Several faculty members acknowledged the fact that they cannot relate to the REM students and do not understand their unique circumstances (Sanczyk et al., 2021b; Yaya-Bryson et al., 2024): "It's [culture] never really been an issue from my perspective, but I'm a white male. Maybe I'm brought up to feel that it's not going to be an issue."

The HBCU context demonstrated a higher awareness of the needs of black students, likely due to the institution's status. However, faculty perspectives still showed deficit-based presumptions, such as this Asian faculty's analysis of their mentoring experiences (Merriweather et

al., 2022):

URM [underrepresented minority] students, they have their own ideas, okay? Not like international students [who] can concentrate on these research projects, but URM students, because they are domestic students, they have a family here, they have other things. So, I just felt that [for] the URM students, you need to really grab them and try to let them be very clear [about] what they need to do.

Another PWI Asian professor shared their views about REM students' weak math backgrounds, saying "They have the potential, but maybe it is not [as] good as others. So, their path towards the final PhD is different from the other classical students." (Merriweather et al., 2022). As these findings show, faculty who do not come from REM backgrounds tend to marginalize minority students, explicitly comparing them to their "classical" or "international" peers with an adverse mindset.

Inevitable Cultural Mismatch

The lack of representation is not the sole issue for the student body; the faculty body also lacks diversity, and it directly creates a mentor-mentee mismatch in the STEM doctoral programs. One of the Black students' comments supports the representation issues: "I would have loved to work with another Black man, but not one is available." The women students shared similar concerns about the lack of women faculty and authority figures who share their ethnic or racial descent (Lambert et al., 2024; Yaya-Bryson and Merriweather, 2025).

Parallel to these findings, Merriweather (2022) underscored that the majority of the international faculty never mentored REM students, which is likely to be a consequence of limited REM representation and focusing on international student recruitment in the US context. In fact, some faculty did not consider culture as a factor in their mentoring relationships when it came to mentoring REM students:

I really don't know how it [mentoring] would be different compared to managing a non-underrepresented minority. [...] I have not worked with those backgrounds or any even... I wouldn't know how different it would be to mentor them versus a non-underrepresented student.

Another domestic faculty explained the similar lack of relatability with these words:

I'm not sure that I actually truly understand the society that he comes from and what unique circumstances he brings to table. I'm not sure that I truly understand his unique circumstances. I try, but I'm not sure that I truly do." (Sanczyk et al., 2021b).

These faculty thoughts were subliminally received by the students because study findings revealed that students perceived a lack of genuine investment, such as time, support, and

connection from their mentor, resulting in their feelings of alienation and invisibility. On the contrary, in Merriweather et al.'s (2022) study, one international Black faculty member with African descent explained how he was able to relate his working-class background to his African American students. The connection he felt led him to become a role model to support his students effectively.

Reluctant advocates

Within this context, invisible walls between mentor and mentee set the stage for reluctance to engage in transparent conversations. Students continue to expend energy assessing their context and positionality to determine their survival strategies, which can be both distracting and exhausting. Minority students recognize the importance of self-advocacy in raising awareness within the departmental and institutional context, and they seek to see their faculty as allies who advocate on their behalf. However, the findings indicate a two-way reluctance to advocacy on both the student and faculty ends. Several students noted that their mentors were unsupportive when they needed to address discriminatory action within the department (Lambert et al., 2023; Sanczyk et al., 2021a; Yaya-Bryson & Merriweather, 2025).

A student stated that he was reluctant to advocate for himself while knowing his mentor already held stereotype threats against him, explaining,

He's [faculty mentor] made numerous comments to me about not being smart enough to be here, that was based on stereotypes. Well, if I voice my opinion when something like this happens to whoever says it to me, then instead of the person who said it getting reprimanded or getting in trouble, it's going to be me for expressing how I felt. (Sanczyk et al., 2021a)

Students expected intentional mentoring from their faculty to acknowledge the racially fueled oppression and guide them with survival techniques for preventing isolation in STEM (Lambert et al., 2023).

Theme 3: Repowering Mentoring Practices Mentoring as a Holistic Approach

The final theme of this meta-analysis revealed that doctoral mentoring requires a holistic approach, and faculty members often lack the training and readiness to achieve this task effectively. According to student and faculty interviews, findings clearly highlighted that students need guidance beyond research, including social-emotional support, inclusive departmental and institutional support, stable sponsorship and funding, and career support (Lambert et al., 2024; Merriweather et al., 2022a; Sanczyk et al., 2021a, 2021b; Yaya-Bryson and

Merriweather, 2025; Yaya-Bryson et al., 2024).

In Lambert and colleagues' study (2024), women students shared their expectations from their mentors as a combination of professional and social-emotional support to succeed in their STEM careers. The social-emotional piece is particularly important for REM students. For instance, Yaya-Bryson and Merriweather (2025) unpacked the concerns of first-generation Latine students about how their mentors need to shift gears from majority mentee groups—typically white, not first-generation, and financially independent—to tailor their mentoring to be less intimidating and more encouraging for mentees who come from challenged and minoritized backgrounds.

Despite the faculty who center their mentoring practices on “doing science,” the findings also suggested that there are few faculty who are conscious of students' diverse needs and view mentoring as more than just scientific discovery (Douglas et al., 2021; Merriweather et al., 2022). They pointed out the importance of expanding their mentees' networks through recommendation letters, conferences, and social events (Sanczyk et al., 2021b).

Need for Institutional Support and Training

In addition to these challenges, the faculty participants expressed their need for institutional support to ensure faculty and student success. They described this need in two ways: stable funding and faculty training.

Faculty members acknowledged the importance of stable funding for increased student retention and a sustainable research agenda (Sanczyk et al., 2021b; Yaya-Bryson et al., 2024). Students' focus on their academic and career success could easily be shadowed by financial worries when they do not have a sustainable wage throughout their doctoral training. One faculty said, “So, in some way, the university has to support, make funds available for students,” and another one said, “I think it's important that students are well supported, whether that be research funds, their stipend, a fellowship that you help them obtain or they obtain, and whatever supplemental resources can be provided. There's no cushion if funding doesn't come through” (Sanczyk et al., 2021b).

Lastly, faculty members frequently expressed their need for faculty training and more departmental and institutional support to improve their mentoring skills. One faculty member from the departmental leadership group said, “Because you know you get to be a mentor, as an advisor, and you never really had any training, and now you're a manager, and a guide, and sometimes a psychologist. So, it's kind of learn by experience was what I went through” (Douglas et al., 2021); another faculty said, “There's no discrete program for preparing faculty. I guess it's just more informal conversations with people” (Sanczyk et al., 2021b). In addition to a

lack of training, findings suggested that some of the faculty members said they were not aware of the professional development opportunities within their institution to improve cross-cultural mentoring practices, which implies a lack of communication among faculty and institutions (Yaya-Bryson et al., 2024).

International faculty members brought up the challenges they face due to their accents, misinterpreting cultural cues, and communication barriers. One Asian man, an HBCU faculty member, said, “Sometimes, I feel like after meeting, was I too harsh? Did I make microaggression? Those things, I always look back on meetings and [think] what can I do?” (Merriweather et al., 2022). Consequently, they acknowledged the need to learn more about their students' expectations and backgrounds to navigate cultural differences (Merriweather et al., 2022; Yaya-Bryson et al., 2024).

Sanczyk and colleagues (2021b) concluded that STEM faculty lacked cultural awareness, which they identified as a prohibiting factor for students to experience enriching and empathetic contexts. Overall, instead of “relying on intuition” and a trial-and-error approach to mentoring, there is a need for a proactive agenda to support all students.

Discussion

The findings of this study highlight the persistent and multifaceted challenges that shape cross-cultural mentoring in STEM doctoral education. While STEM research is often perceived and practiced as objective or scientifically pragmatic, the experiences of culturally diverse doctoral students reveal that power, identity, and systemic norms have a profound influence on doctoral mentoring relationships.

Findings from faculty perceptions present a strong normative assumption of science, describing mentoring as a universal and objective task, which presumes the sameness of all students and further compounds the challenges faced by REM students. Literature indicates that mentoring and training practices in STEM often adhere to a standardized model, characterized by a “mental programming” that overlooks students' unique cultural identities, lived experiences, and personal trajectories (Adams et al., 2018; Hofstede, 2001; Wright et al., 2023). This hegemonic normative approach can render students' diverse needs invisible, leading to mismatches in expectations and a lack of social capital necessary for thriving in the STEM society.

Paradoxically, the meta-analysis findings highlight that faculty members hold implicit biases and deficit-based presumptions against their minoritized students, challenging their justification of the ideology of sameness, which may significantly influence the formation of mentoring relationships. The literature supports this contradiction, pointing out a lack of

intentional reflection and mentors' unconscious tendencies toward stereotyping students based on race, nationality, language proficiency, or perceived academic preparedness (McGee & Martin, 2011; Sue et al., 2007; Warren & Bordoloi, 2023). These biases can lead to discriminatory treatment in terms of access to research opportunities, quality of feedback, and professional advocacy. Moreover, relevant studies underscore that perceiving biases can undermine students' confidence, limit their engagement, and contribute to the high attrition rates seen among REM doctoral students (Curtin et al., 2016; Posselt, 2020).

Students, on the other hand, acknowledged the importance of holistic mentoring relationships, considering their social and emotional needs as a valid and central component to their success. They enter doctoral programs with a desire for relational mentoring, characterized by empathy, encouragement, and commitment (Allen and Eby, 2008; Curtin et al., 2016; Gibbs et al., 2014). When these expectations are unmet or dismissed as unprofessional, students may feel isolated or devalued, further straining the mentoring relationship. In fact, in the meta-analysis reports, several students reflected on their feelings and interactions where faculty and department projected deficit-based ideas regarding students' abilities and potential. Parallel to these findings, in a different study, Gibbs and colleagues (2014) collected data from 1500 biomedical science doctoral students to analyze their career interest patterns, where they compared REM groups with dominant groups (i.e., well-represented, encompassing White, and Asian/Asian American scientists). Their findings indicated no significant differences in interest patterns at the beginning of the doctoral programs. However, at the degree completion phase, they found that REM groups demonstrated significantly lower interest in academia compared to their White and Asian counterparts. In addition, their findings showed that higher interest in pursuing academic roles was positively associated with higher doctoral mentor involvement and departmental support. Aligning with the NSF AGEP goals (NSF, n.d.), Gibbs et al. study clearly underlines the importance of mentoring relationships for creating a more diverse STEM faculty pipeline.

Another central issue that emerged from this meta-analysis is the lack of representation within STEM doctoral programs, which remain overwhelmingly white and male-dominated (NSF, 2023; Ong et al., 2017). This underrepresentation in faculty and leadership positions leads to a cultural mismatch for REM students, which can alienate them from their marginalized background in order to be successful or reinforce a narrow perception of self, implying they do not fit the successful scientist profile (McGee, 2016; McGee & Martin, 2011). In parallel with the cultural mismatch theory, both scenarios are likely to harm REM students' developmental progress and prevent them from feeling included,

understood, or fully supported in their academic environments (Stephens & Townsend, 2015).

Supporting the social capital theory, in cases of adverse perceptions and experiences, students may seek a safe place to overcome stress and isolation. Ong and colleagues (2017) described safe places as counterspaces that allow students to coexist within the STEM context, where microaggressions are more likely to occur due to race, ethnicity, and gender. In this study, the researchers particularly explored a group with significantly low representation: REM women graduate students and professionals. Their findings indicated that the students use various strategies to create their safe space, including engaging with peer groups, non-STEM campus groups, diversity conferences, and mentoring relationships. The participants were less likely to describe their institutions and departments as counterspaces (Ong et al., 2017).

In this regard, creating safe spaces in STEM doctoral programs for all students requires a shift in direction toward culturally liberative mentoring practices. This approach centers the student's identity, experiences, and goals, affirming their cultural backgrounds as sources of strength rather than deficits. Culturally liberative institutions, departments, and faculty mentors actively challenge dominant academic norms, address systemic inequities, and co-construct mentoring relationships based on mutual respect, trust, and accountability (Adams et al., 2018; Wright et al., 2023; Yaya-Bryson et al., 2024). Achieving a holistic and culturally liberative STEM context requires willful efforts for institutional change and professional development programs for faculty and staff, which could also be explained by Bronfenbrenner's PPCT model, where interconnected contexts determine human development. To overcome resistance to change, complex and multilayered strategies are necessary, such as institutional standardization, guidelines, training programs, and formal faculty evaluation frameworks (Wright et al., 2023). Adjustments to these changes would require mentors to engage in ongoing self-reflection, recognize the limits of their own perspectives, and gradually, embrace a more holistic view of student development along with their own personal development.

Conclusion

To conclude, cross-cultural STEM doctoral mentoring cannot be disentangled from the broader systems of power and culture that shape academic life. Efforts to improve doctoral mentoring must move beyond surface-level diversity initiatives to fundamentally rethink how mentoring is practiced, assessed, and rewarded. Culturally liberative mentoring stands not just as a promising practice for REM doctoral students within the STEM fields, but as a transformative framework for the future of inclusive and equitable institutions for all.

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