Editors' Suggestion | Featured in Physics

How women and lesbian, gay, bisexual, transgender, and queer physics doctoral students navigate graduate education: The roles of professional environments and social networks

Justin A. Gutzwa,[1] Ramón S. Barthelemy,[2] Camila Amaral,[2] Madison Swirtz,[2] Adrienne Traxler,[3] and Charles Henderson[4]

[1]*Department of Educational Leadership, Michigan State University, East Lansing, Michigan, USA*
[2]*Department of Physics & Astronomy, University of Utah, Salt Lake City, Michigan, USA*
[3]*Department of Science Education, University of Copenhagen, Copenhagen, Denmark*
[4]*Department of Physics and Mallinson Institute for Science Education, Western Michigan University, Kalamazoo, Michigan, USA*

(Received 31 January 2024; accepted 14 June 2024; published 12 September 2024)

Despite knowing physics and astronomy doctoral programs are laden with identity-based inequities, they continue to push minoritized students to the margins. This qualitative social network analysis of 100 women and/or lesbian, gay, bisexual, transgender, queer, and more (LGBT+) physics and astronomy Ph.D.'s explores how minoritized physics and astronomy students utilize social networks to navigate departmental exclusion. Our findings indicate that many of the participants' identities were often unacknowledged or negatively addressed within their graduate education, with only four participants reporting a positive or favorable experience during this period of their career. Direct support from peers, faculty, and identity-based affinity groups was necessary for participants to navigate their educations. This study demonstrated that generic best practices often cannot fully support the diverse range of persons who come to physics and that identity-neutral values in physics further isolate students by insinuating that their own minoritized experiences are not valid.

DOI: 10.1103/PhysRevPhysEducRes.20.020115

I. INTRODUCTION AND BACKGROUND LITERATURE

The minoritization of students in science, technology, engineering, and mathematics (STEM) education fields along raced, gendered, and sexual lines is a well understood yet still disconcertingly pervasive reality in higher education research [1,2]. These realities are particularly prevalent within physics and related disciplines and have become a topic of concern in the evolving field of physics education research [3–5]. The number of physics bachelor's degrees conferred annually has readily increased since the 1990s [6]. Still, physics and its associated subdisciplines continue to have low rates of degree attainment and faculty representation for women and People of Color: Black and Latina women, for example, currently make up only 11% of physics bachelor's degree holders, 8% of doctoral degree holders, and 6% of physics faculty at doctoral-granting institutions [7]. Further, the pervasive nature of harassment and discrimination against women [8–14], Communities of Color [15], and LGBTQ+ (lesbian, gay, bisexual, transgender, queer, and more) communities [16–18] in physics underscores the necessity of interrogating not just the ways physics education perpetuates systemic minoritization, but also the root causes of racism, cisheterogenderism, and other modes of domination in postsecondary physics education.

Graduate education in physics, astronomy, and related fields (simplified herein to "physics and astronomy") has become an emerging area of interest among physics education research scholars, especially as the fields work to reckon with their histories of racialized and gendered exclusion [16,19–21]. While this work has varied in its approaches and findings, a majority of scholars have looked at the experience of those "underrepresented" or "marginalized" in physics and astronomy [22–26], or how standard examinations prevent marginalized communities from getting into graduate programs and do not predict success [25–27].

Research on women's experiences within physics and astronomy graduate education has demonstrated a tapestry of barriers and challenges that impede their success in the field, including rampant experiences of gendered microaggressions and hostile sexism [22,28] and challenges finding supportive mentorship [29]. Although no work, to our knowledge, has been done specifically on queer persons in physics and astronomy graduate education, the growing literature on the experiences of queer physicists more generally [16,21,29,30] has demonstrated the prevalence

of hostile climates, exclusionary behavior, and intersecting modes of domination (e.g., queered racism; cisheterogenderism) in the workplace. Clear from this growing literature is the necessity to further understand the experiences of minoritized communities in physics and astronomy graduate education.

The decades-long neoliberal push to view STEM fields as "identity-neutral" [1] continues to shape the culture of physics and astronomy graduate programs; these tensions have more specifically been documented within physics and astronomy fields for decades, with scholars long problematizing physics' disciplinary "culture of no culture" [31,32]. Forced identity neutrality, which we define as the passing off of the blatant disregard of the impact that an individual's social identities have on their experiences within a particular discipline through the logic that being "neutral" toward identity has the ability to level the playing field for all people in that discipline, ignores the systems of domination which exacerbate the inequities minoritized people experience in STEM departments rather than contending with them. Such tensions also perpetuate the deficit-based mentalities that minoritized students in STEM are often viewed through [33], meaning that STEM departments often shirk the burden of success onto minoritized students directly [32].

One way that minoritized students develop the capital needed to navigate higher education is through the wealth of their communities [34]; exploring how minoritized students develop and use their social networks to navigate exclusionary departments centers their identities as assets and can help illuminate how students resist normative identity-neutrality in physics and astronomy. This paper presents findings from a qualitative social network analysis of 100 women and/or LGBT+ people who hold a Ph.D. in physics, astronomy, or a related field. In the literature, many women and LGBTQ+ persons experience similar axes of marginalization, making them a unique group to consider together. In this analysis, however, it is also important that we tend to race and other minoritized identities when relevant to the stories of participants even though the main focus of the paper is on gender and sexual identity. We present participant narratives to address two research questions:

I) How do participants describe the environments and experiences they encountered in their doctoral programs?
II) How did participants build and utilize their social networks to navigate these departmental climates?

Findings interrogate how physics and astronomy programs historically fail to support minoritized students, how normative identity neutrality in physics and astronomy exacerbates the systemic exclusion minoritized students encounter during their doctoral programs, and ultimately suggest avenues for justice-based departmental and disciplinary reform in physics and astronomy.

II. THEORETICAL FRAMEWORK

Funds of science identity offers a critical conceptual model to help actualize power-disruptive reform in STEM higher education by celebrating the wealth of knowledge students develop through their lived experiences and identities and bring to their STEM programs. Wofford and Gutzwa's [35] operationalization of funds of identity merges critical theoretical innovations in science identity work [36,37] with Esteban-Guitart's [38,39] coining of funds of identity, defined by Gutzwa as "the lessons individuals internalize from family resources that help them make meaning of the world and of themselves" [40] (p. 305). First theorized in K-12 contexts as an identity-centered expansion on funds of knowledge work initially carried out in the 1990s, funds of identity has seen increased usage as a theoretical and sometimes methodological approach to equity-minded research in postsecondary education, particularly scholarship ascertaining the embodied epistemologies of transgender, nonbinary, and gender non-conforming (trans) college students [40,41]. In their work in this area, Gutzwa highlights several examples of funds of identity that trans students develop throughout their lives, such as how some trans students learn different tactics for self-preservation (e.g., selectively choosing where, when, and how to disclose and perform their trans identities; the importance of developing kinship networks with other trans people) that they employ to help subvert cisheteronormative power dynamics in collegiate learning environments [40].

Again building on K-12 STEM education work that has incorporated funds of knowledge perspectives into research and pedagogy [42,43], Wofford and Gutzwa extend funds of identity as a concept to STEM education contexts, offering it as one way of utilizing "justice-oriented and asset-based frameworks for … STEM student development, focusing on contextually situated and culturally relevant identity development," [35] (p. 66). As participants in the present study reflected on their graduate education experiences, many described the ways direct happenings in their doctoral programs—for better and (sadly often) for worse—shaped their understandings of their personal and professional identities, as well as illuminated ways they made sense of holding minoritized identities within the identity-neutral space of STEM. Our present use of funds of science identity as a theoretical lens speaks to our desire to understand these experiences, which far too frequently are discussed through deficit lenses [33,35], through a firmly and bluntly asset-based vantage in order to disrupt the deficit-framing of identity broadly that is latent in STEM disciplines.

Wofford and Gutzwa [35] propose funds of science identity as a way to explore how individuals' experiences before, during, and following their engagement with STEM departments can be harnessed to disrupt inequity societally and within STEM spaces more broadly. Namely, they argue

that when STEM departments and the learning spaces they house amplify students' identity-based ways of knowing rather than silencing them, these spaces can be transformed into identity-affirming spaces that are able to contend with the systems of power that exacerbate oppression at both disciplinary and societal levels. Though their initial postulation of funds of science identity centered undergraduate students and the self-authored epistemologies they form at the nexus of their social and science identities, we feel funds of science identity has unique utility as a framework for exploring the experiences of graduate students, who engage nuanced modalities of socialization, professionalization, and ultimately exclusion during their doctoral experiences in STEM fields [44,45].

Core to the funds of science identity approach is naming and disrupting systems of oppression by prioritizing the funds students utilize to subvert these modes of domination. Wofford and Gutzwa [35] offer a multistage, asset-based model of understanding how prioritizing students' self-authored epistemologies can disrupt systemic oppression in STEM higher education across three main dimensions:

- Dimension 1: Individual, or, how students leverage their lived experiences to build their science identities or the extent to which they feel "like" a science person. Scholars and practitioners must invest in learning about how students bring their social identities into STEM environments.
- Dimension 2: Institutional, or, how scholars and practitioners can disrupt injustices via creating identity-affirming spaces (i.e., physical or digital spaces where students can create identity artifacts that represent culturally mediated thinking). By creating identity-affirming spaces, scholars and practitioners can combat discriminatory norms, cultures, and values that are perpetuated through the maintenance of exclusionary higher education contexts.
- Dimension 3: Systemic, or, how scholars and practitioners can account for and rewrite the futures of disciplinary context and power. In ascertaining and uplifting students' funds of science identity, it is crucial to examine the development of funds of science identity within STEM disciplinary histories, including how disciplinary histories are characterized by systems of oppression.

The findings presented in this article, and our subsequent discussion of these findings, explore how the tensions described by participants map onto these three dimensions. By focusing our inquiry and analysis on the lived experiences of individual students, most of our discussion is located at dimension 1. While many participants identified spaces that did not affirm their identities, some also highlighted those that did (including, but not limited to, identity-specific affinity groups, conferences, and even some classroom spaces); as such, our analysis also interrogates the role that institutional-level spaces played in the lived experiences of participants, therein also engaging dimension 2. As in Wofford and Gutzwa's original model, these conversations on dimension 1 and 2 inform our engagement with dimension 3 in our discussion and implications, which offer system-level commentary and recommendations for physics, astronomy, and related disciplines.

In sitting with participants' narratives of how their social networks helped them contend with the racism, sexism, cisheterogenderism, ableism, and other modalities of oppression they encountered in their doctoral programs, we came to understand the funds of science identity that students developed through their networks were then utilized by participants as forms of what Yosso [34] describes as navigational capital, or the "skills of maneuvering through social institutions" not built with minoritized communities "in mind" (p. 80). The agential navigational strategies participants employed to navigate hostile environments are inextricably connected to their identities. Said differently, we view the individual funds of identity that participants uniquely developed in their own experiences before, during, and sometimes after graduate school as being integral to the ways that they made sense of and navigated their time as doctoral students. By viewing these funds of participants' identities as forms of capital, it becomes possible to challenge the deficit-based, identity-neutral nature of physics and astronomy departments through the asset-based celebration of identity in STEM environments.

III. RESEARCH DESIGN

Data presented in this article were collected through a larger qualitative social network analysis [46,47] of 100 people who hold a Ph.D. in physics, astronomy, or a related field; identify as women and/or LGBTQ+; and work in the United States. Throughout data collection and analysis, aspects of individuals' narratives regarding their graduate school experiences emerged as particularly salient for many participants, encouraging us to move forward in writing a manuscript that paid close attention to these experiences. Lena (participant; pseudonym) shared in her interview the importance of storytelling within our collection of data and her own story, "There's a story to all of this, right? The storytelling element matters." With this ethos in mind, this manuscript is methodologically presented as a social justice narrative inquiry [48]. In this section, we begin by describing the methodology of social justice narrative inquiry, before outlining the original study's implementation of egocentric social network analysis methods. In this discussion, we outline participant recruitment methods, data collection strategies, and our approach

to data analysis. We conclude with a discussion of our positionalities as they shape the present work, particularly the perspectives that shape our engagement with participants in the field as well as the data we collected.

A. Methodology: Social justice narrative inquiry

Social justice narrative inquiry adopts QueerCrit perspectives [48] to critically interrogate the way individuals interact with multiple forms of domination [49]. As individuals' funds of identity are individually contextual and thus unique from person to person, "narrative inquiry provides an ideal structure for this study as it allows for participants to be viewed as individuals with nuanced lived experiences" [40] (p. 307). In particular, the critical aims of social justice narrative inquiry are well suited to exploring the ways gendered, racial, sexual, and other modalities of minoritization permeate throughout physics and astronomy departments as it allows for the naming and disruption of systems of domination necessary in funds of science identity work [35].

B. Methods: Egocentric network analysis

Data presented in the present manuscript were collected through a study that employed an egocentric research design [47], an approach that allowed us to gather information about a group that is large and diffuse enough where a whole network analysis (e.g., an analysis of "all U.S. physicists" or "all students in a department") would not be feasible. Egocentric network analysis allowed for the experiences and connections of individuals in the subset of people sampled to emerge as the subject of interest, as opposed to other methods of social network analysis which emphasize the position that an individual occupies within a network or how the whole of a network is structured as the unit of analysis [47]. In this section, we outline our implementation of egocentric modes of network analysis, starting with participant recruitment and carrying through to our analysis of collected data.

1. Participant recruitment

Guided by the literature as well as our own experiences navigating physics and physics education while holding minoritized identities, our understanding of underrepresented communities in physics, astronomy, and related fields was reliant on how gender and sexuality demographic discrepancies are demonstrably palpable within the physical sciences [22,23,30]. As such, when recruiting participants, we focused on locating individuals who identify as either women and/or LGBTQ+ currently working in the United States who hold a Ph.D. in physics, astronomy, or a closely related field. Within this larger community of scientists, we purposefully sampled along several key lines: mainly sector of employment and intersecting social identities. First, the participants of this study work in academia (e.g., tenure or career-line faculty appointments), government (e.g., conducting research at a national lab), or industry (e.g., working at a private research firm; working in science communications) sectors; for some participants, these sectors overlapped (e.g., multiple jobs joint appointments). We selected participants to ensure we would have a similar percentage of people in each sector in order to ensure a broad range of total experiences were being represented. Additionally, we aimed to complicate our understanding of underrepresentation and minoritization within physics and astronomy by intentionally reaching out to and recruiting scientists who hold multiple, intersecting minoritized identities beyond just gender and/or sexuality. While difficult in a 100-person sample of a field that is still overwhelmingly white, cisgender, and heterosexual [7], this intentionality allowed us to unpack personal narratives of the intersections of race and racism, gender and (trans)misogyny, sexuality and homophobia, and other modalities of domination as they impacted participants uniquely during data collection and analysis.

With these considerations in mind, we interviewed 100 participants in the larger study, with at least one-third of participants holding a job in each career sector (academic, government, and private) and all holding at least one identity that aligned each of the main recruitment criteria (identifying as a woman or as LGBTQ+). Figure 1 shows the number of participants in each job sector, illustrating the predominance of interviewees in academia. Though we met our goal of having one-third of the participants in each sector, considering the overlaps, we have more data on physicists and astronomers in academia than in other sectors. To find participants for this research, we first built a questionnaire on Qualtrics with questions related to the respondents' demographics, which included questions that

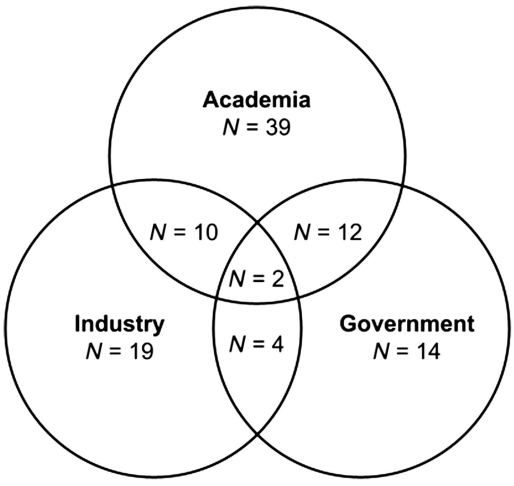

FIG. 1. Participants per job sector. A total of 63 in academia, 35 in industry, and 32 in government sectors were interviewed, with overlaps of multiple sectors noted separately from those who only belonged to one sector.

would be used to assess whether or not the respondents fit the research criteria. After institutional review board (IRB) approval, this questionnaire was posted on social media (LinkedIn and Twitter), shared on Listservs, and sent to people within the researchers' networks. We also did snowball sampling [50] once the interviews had started by inviting participants to share our recruitment call with people in their networks whose identities and experiences matched up with the study's recruitment criteria.

2. Methods of data collection

Participants were asked to engage in one semistructured interview [51] lasting approximately one hour in length in order to complete participation in the study. The entire research team participated in the construction of the interview protocol. The first draft was developed by Ramón, as lead PI, and used both social support and social capital lenses in framing the questions. This first version was revised in the conversation between two postdocs and a graduate student and later discussed with all authors. Ten preliminary interviews were conducted to test the revised protocol; after minor changes were made, we proceeded with participant recruitment and interviews. During interviews, participants were also asked to produce a sociogram [52,53], a diagram that allowed participants to visually map their networks, including who and what groups those networks comprised and how proximally "close" each individual or group was to the participant. The analysis presented in this article is a subset of the qualitative interview data specifically pertaining to the narratives participants shared about their graduate school experiences. As such, the quantitative network data were not included, and the constructed egocentric networks served as an interview artifact that helped participants frame their experiences from the perspective of their social interactions.

3. Analysis

After the first ten interviews were conducted, the three team members initially responsible for data analysis built out an initial, working, and living codebook that pulled from thematic (e.g., types of support individuals received within their networks; decision-making processes in navigating careers) and structural (e.g., organizations, people, and locations where support was received) approaches to making sense of the data [54]. After applying this initial codebook to the first ten interviews, the research team continued to build on the codebook throughout the collection and analysis of the remaining 90 interviews; newly added codes, when relevant, were also added to the ten initially coded interviews. Each interview was transcribed by a specialized service provider and then coded using MAXQDA.

The codebook relied on both inductive and deductive approaches to coding. The range of questions asked in interviews and the range of experiences detailed through participants' sociograms inspired a thematic coding approach [54] rooted in the original study's research questions (which were broader and more fully encompassed the magnitude of the study than the more specialized questions which guide this particular paper); one such code was an organizational thematic code of "graduate school experiences." For the present article, all interview excerpts coded with this thematic code were pulled and organized by the research team into distinct findings presented in the following section; of the total 100 participants, 93 discussed their graduate school experiences across a combined number of 578 segments. This secondary analytic process was carried out separately from the analysis of the full findings and was guided by the dimensions of funds of science identity as theorized by Wofford and Gutzwa [35] as well as Yosso's [34] conceptualization of navigational capital. By separating coded excerpts into "how were experiences described" and "how were networks used to navigate experiences," we were able to organically address our research questions in this text.

4. Researcher positionality

Almost all members of the research team are either currently experiencing or have formerly experienced doctoral-level graduate programs in our own career trajectories while holding minoritized identities; it is our own experiences navigating inequity, of seeing others experience intersecting modalities of domination and inequity, and (in the case of Justin, Ramón, Adrienne, and Charles) mentoring our own students as they encounter oppressive and exclusionary climates in the graduate programs we work in as tenure-track faculty members that brings us to the present work. All authors with the exception of Justin completed or are currently completing doctoral degree programs in STEM fields (four in physics; one in applied mathematics and statistics), while Justin completed a doctoral degree in higher education and worked closely with a range of STEM equity research groups during their degree program. As such, our professional and personal experiences as former or current doctoral students heavily shaped our interpretation of findings, as well as the ways that Justin, Camila, and Madison engaged with participants during data collection.

Beyond the general commonalities of our experiences, our individual experiences and identities also shaped our engagement with the findings shared in this manuscript. Justin (they/them) identifies as a white, trans, nonbinary, queer, disabled scholar-practitioner, and currently serves as an assistant professor in a college of education at a large, public university in the United States. Their status as a higher education scholar was often discussed in interviews as a mode of disrupting the traditional expectations of identity avoidance that participants might have held entering a STEM education study, and their prior experiences navigating doctoral programs as a trans student and

TABLE I. Quoted participant demographics.

Pseudonym	Race or ethnicity	Gender	Sexuality	Industry
Chandler	White	Man	Queer[a]	Academic
Cirie	Black	Woman	Queer	Academic
Da'Vonne	Black	Woman	Queer	Industry
Damien	White	Man	Queer	Academic
Ethan	White	Man	Queer	Academic
Felicia	White	Woman	Queer	Academic
Janelle	White	Woman	Heterosexual	Academic
Juan	Latino	Man	Queer	Academic
Kacey	White	Woman	Queer	Academic; government
Kerry	White	Woman	Heterosexual	Academic
Lena	White	Woman	Queer	Government
Mateo	White	Man	Queer	Academic; government
Melissa	White	Woman	Heterosexual	Academic
Paolo	White	Man	Queer	Industry
Paul	White	Man	Queer	Academic
Phoebe	White	Woman	Heterosexual	Industry
Priyanka	South Asian	Woman	Heterosexual	Academic; government
Sam	White	Nonbinary; woman	Queer	Academic
Sequoia	White	Nonbinary; woman	Queer	Academic
Stella	Latina	Woman	Queer[b]	Industry
Velma	White	Noninary	Queer	Academic; government

[a]We use the word "queer" as opposed to "LGBT," "LGBTQ," or "LGBTQ+" to express an umbrella term to categorize nonheterosexual identities.

[b]While Stella currently identifies as queer, she did not identify as queer during her time as a graduate student.

advocating for racial and gender-based equity reform within the microcosms of the research teams they worked on as a graduate student created avenues for shared empathy with the experiences participants shared during interviews. Ramón (he/him) is a queer Hispanic physics education researcher who has worked on issues of gender and LGBTQ+ identity in physics and astronomy for over a decade. He came to this work as both a physicist and a member of the community being studied. Camila (she/her) has been read as white in her home country and since coming to the United States is easily recognized as Latina, experiencing part of the racism and exclusionary behavior typically directed toward Latina/o people. Her identity as a queer Woman of Color was perceived during the interviews with people with shared identities, which to a certain extent shaped the process of collecting and analyzing data. Madison (they/them) is a queer white graduate student in physics education research, and as such is currently navigating the struggles of being visibly queer as a graduate student in a physics department. Several participants viewed them as a young researcher to be nurtured and as such spoke about their graduate experiences as a way to give advice and offer mentorship. Adrienne (she/her) is a white physicist. Her career trajectory (physics to education to applied mathematics to physics to science education) has sometimes placed her in a peripheral position or required careful framing to find jobs in physics departments, which shapes her reading of participants' comments on career transitions. Finally, Charles (he/him) is a white male physics education researcher who does not identify in the communities discussed here, but has been an active mentor and ally to the co-authors conducting this work, and more broadly in the physics education research community.

IV. FINDINGS

Our findings are organized in line with the research questions that guide this study. First, we explore how participants described and made sense of their graduate school experiences and departments, which many referred to as "toxic," exclusionary, or otherwise oppressive. After, we explore the ways that participants built social networks and utilized these networks in navigating the toxic exclusion they encountered during graduate school, particularly emphasizing the relationships participants built with peers and program faculty and the community they developed through participation in identity-based affinity groups (e.g., Students of Color groups, LGBTQ+ student groups; groups for women in STEM). Throughout our description of findings as they relate to each research question, we explore how the tensions described by participants map into the three dimensions of Wofford and Gutzwa's [35] articulation of funds of science identity: individual-level identity-based experiences; reflections on the presence (and lack) of departmental-level spaces that affirm participants' social identities; and the ways that societal systems of power are perpetuated throughout physics and astronomy

graduate education and reified through physics and astronomy professions at a disciplinary level.

While the data presented in this section emerged from the full analysis of our team's interviews with all 93 participants in the present study who described their graduate experiences, it is impossible to include quotations from 93 individual narratives within the spatial constraints of a journal-length manuscript; as such, the narratives presented in our results were chosen to simultaneously represent the broader swath of experiences reported by the 93 participants who discussed their journeys navigating graduate education while also highlighting the individual nuances that exist between many of their experiences. Table I offers the demographic information, including identities and employment sectors, of the participants who are specifically quoted in the findings.

A. Research question I: How do participants describe the environments and experiences they encountered in their doctoral programs?

Only 4 of the 93 participants who discussed their graduate school experiences specifically reported having an overall positive or favorable experience in graduate school, while 89 participants reported having an overall negative experience. Their narratives demonstrate how physics and astronomy doctoral programs failed to create identity-affirming spaces for these minoritized students. As individuals who enter graduate education with a diverging myriad of individual dimensions to their identities, the lack of access to identity-affirming spaces within the institutional dimensions of their graduate experiences led some to seek such spaces outside of their departments or institutions, while others worked to create such spaces within their home departments. Still more internalized a lack of identity-affirming spaces as a message that those holding their social identities did not and likely could never thrive in the fields of physics and astronomy, indicative of the system-level power structures that further minoritization in individual disciplines and across society alike [35]. Clear across the narratives presented is the need for more identity-affirming spaces within physics and astronomy departments that are intentionally created to support minoritized students, particularly those who hold multiple, intersecting minoritized identities. Two main themes emerged from research question 1: (1) that identity does not belong in physics, and (2) the toxicity of faculty, peers, and departments.

1. Identity not included in physics

Throughout the interviews, the narratives of the participants described an educational context where identity was seen as unnecessary and superfluous to a graduate physics education. This understanding was conveyed to participants through both action and direct communication. As Sequoia explained "I've been very bluntly told who you are as a person doesn't matter in the physics classroom. That's definitely not a thing that's been under the radar in any way." The process of identity erasure in physics led to the internalization of what Ong [55] describes as "identity fragmentation," or a forced separation and compartmentalization of one's social and professional identities, within many of the stories revealed in the interviews. Damien, for example, was involved in local advocacy and organizing efforts in support of queer rights and actively developed a strong sense of his queer identity outside of graduate school. He described, however, that he felt that his activism needed to remain disconnected from his scientific pursuits: "I was out protesting in the street, but then I was doing physics in the lab. I wasn't really kind of connecting those two." Because funds of identity demonstrate how people make sense of their identities in relation to the academic, professional, and broader societal strata they engage throughout their lives, Damien developed a navigational understanding that physics, as a discipline, separates "political" manifestations of social identity from the "objective" aspirations of science research. Although outside the field of his career, Damien was still able to build this individual fund of his identity, which in turn became a form of capital he relied on for navigating the world of physics. Put simply, Damien not only built his own funds of identity external to physics to support him in the field but also was able to find space to utilize these funds of his identity outside of the disciplinary contexts of physics.

The internalization of identity incongruity was also reified through interactions with faculty, including a continued surprise at their students' queer relationships, even when those faculty worked in programs where many students identified as being from the LGBTQ+ community. However, some participants noted that even the queer people in their departments at times did not discuss their sexual identities with one another:

> Anytime a professor would find out about somebody's partner they would just be shocked, and it was not because they were like, "How taboo?" but because they just you know weren't expecting it, because it just wasn't thought of. I was like, "Seriously? Like 50% of your female population here is gay. How has no one talked about this?" 'cause no one actually acknowledged it to each other." (Felicia)

For others in the sample, merely existing was a political statement against the hegemonic monoculture that can be physics. Said differently, some participants expressed that just by existing in the field they were able to create identity-affirming spaces for themselves and members of their communities. In turn, these spaces offered them the ability to develop and utilize their funds of identity by disrupting the overall hegemony of physics. Lena described this form of political resistance in the context of conferences,

where they were one of very few women, let alone the only LGBTQ+ person, in attendance:

> Being a woman in physics, and an unstated LGBTQ person in physics, is inherently itself a political act. And so while I never meant to be in a political mind frame, I couldn't help but be so. Just to survive in a PhD environment in physics where sometimes you show up at a conference and you're literally one in 100 or maybe two or three out of 100 women in the room, let alone LGBTQ, that just felt odd.

Compounding these experiences was a described lack of visibility of students and mentors who shared identities with the participants, another example of an institutional barrier that can impact a person developing their funds of identity. Lack of visibility of other minoritized communities manifested differently for some participants, especially for queer participants who were often unable to find an inclusive graduate program: "I tried to get advice on how do I find an institution that doesn't discriminate against queer people? Like, what do I do? I didn't really get any advice on that" (Damien). Some participants spoke to their (in)abilities to find community with other queer people in their home departments. Even when in a graduate program where queer people existed, however, some participants were not aware of their presence:

> I didn't find out until I was more into my graduate years that half of the women there were bi or lesbian, and that several of the men were at least bi or somewhere on the ace spectrum. It was just, you don't talk about that, except for the people who literally would wear it on their tattoos so you would know. It just wasn't talked about. (Felicia)

Paolo similarly recounted the time and place he realized there was another queer man in his program:

> There was another Ph.D. student a few years ahead of me that was queer. But I only found out…[when] I met him with his boyfriend at the time in a gay club. And I was just like, "Oh, funny meeting you here".

Of course, not all people who share some minoritized identity will become friends. Although some participants were able to locate other visibly queer people within their programs, not all developed strong interpersonal bonds with the other visibly queer students based purely on differences in personalities, interests, or other life factors. This demonstrates the need for institutional support in building spaces that affirm students' identities to facilitate their development of the funds of their identities they bring with them to thee curricular, research, and other spaces within physics and astronomy departments. It also suggests that the responsibility of supporting students' identities should fall on all members of a department, and not just minoritized students, staff, and faculty.

> It was me and one other person who were the queer people in the department. And we were within the same sort of social circles, but we were kind of just very different people, so we didn't hang out much. We saw each other a lot, but we… were kind of doing our own thing. So there was basically no queer community in grad school, and I did not find a queer community outside of the department when I was there.

Queer identity was not the only identity axis that impacted participant experiences. Race was particularly salient for multiple participants in navigating the visibility of their departments. Priyanka, Da'Vonne, Stella, and many other Women of Color particularly noted that they often noticed that they were the only Women of Color in their departments, let alone some of the only Women of Color on their campuses. This lack of representation signaled a similar lack of belonging, as Priyanka noted: "I think it was at least three or four years before I saw the first Black student I ever saw in graduate school. I was like, wait, there are no Black people here." Most Women of Color described having to seek community with other People of Color either in other areas on campus or outside of campus all together. Stella, for example, described an inclusive STEM conference as the only place where she was able to build community with other racially minoritized people in physics and astronomy, especially coming from a predominantly white program:

> There were so many other People of Color… I think I had not even met another Latina astronomer at that point in my career. And so that was a huge moment of impact for me. It was a really elevated, amazing conference, but it was only a few days, and then I had to go back. I actually didn't go to a PWI for my Ph.D., it's actually a primarily Black institution, but the program itself was incredibly white—it's almost completely white—so at the Ph.D. level, I was not interacting with almost anybody else of Color.

Through encountering the sheer lack of representation of other People of Color, particularly other Women of Color, participants like Priyanka and Stella developed an understanding that not just identity broadly did not belong in physics and astronomy, but specifically that *their* intersecting minoritized identities as Women of Color had no place in STEM graduate programs. Such a realization, and reality for many, is a key institutional dimension limiting the full expression of one's self, as well as limiting their ability to

build and utilize funds of their identity. These feelings of exclusion experienced by queer participants and Participants of Color were exacerbated by the toxicity they received through interactions with faculty, peers, and their departments writ large.

2. Toxicity of faculty, peers, and departments

Multiple participants narrated their own stories by using the word "toxic" and closely related synonyms to describe their relationships with other members of their academic community. Toxicity was described in two main ways: toxic experiences of misogyny, queerphobia, and racialized aggressions as perpetuated by faculty, peers, and departments; and toxicity through unhealthy working relationships with faculty advisors and mentors. In this section, we outline how each modality of toxicity adversely impacted minoritized students in their graduate programs. Participants had to navigate these challenges while creating their own capital to succeed despite their exclusion and negative personal experiences.

Identity-based aggressions. Misogyny, which we define as discriminatory attitudes and behavior against women, appeared throughout the narratives of women and femme participants. Priyanka, for example, described seeing "a lot of shit in graduate school." Most salient was the memory of watching another woman graduate student in her department be ostracized after coming forward to the department with allegations of sexual harassment against a man in a position of power over her. This woman ultimately left the program and university altogether, a decision Priyanka felt her peer made directly as a result of the othering and silencing she experienced following disclosing abuse. Priyanka internalized this event as a warning that ultimately dissuaded her from coming forward about her own experiences of harassment from a man who was her colleague in the department:

> So when I had a colleague who was making passes at me and making me uncomfortable…I didn't even think about telling anybody, because I could see what was happening in the department. Where would I get? It just wasn't an option in that kind of environment.

Disappointingly, had the department responded in full to the issues at hand it may have functioned as a way to rewrite the future of power in this disciplinary context. Within this disruption, a greater possibility may have emerged for a stronger and more inclusive environment that would promote the development of funds of identity rather than silencing participants from coming forward with their own experiences. Other participants shared similar frustrations with the level of directly oppressive messages they heard, received, and observed during their academic careers. Lena, for example, described that she left academia "angrily," stating her decision to move to non-academic employment sectors "had something to do with how welcomed" she did not feel in the community: "It feels as if there is gate keeping in physics and every other institution, not just in academia, but across all of it. […] I am frustrated by a million microaggressions that I received as a woman." Stories of Priyanka and Lena demonstrate the ways that, for many women, physics and astronomy departments proved to be the diametric opposites of what Wofford & Gutzwa [35] describe as identity-affirming spaces: by actively reproducing misogynistic hostility, the physics and astronomy departments' many women participants encountered during their graduate careers contributed to the understanding that the academy was not an environment where women scientists could be respected and thrive.

Misogyny worked in complex ways for participants and manifested differently based on educational stage and life circumstances. Melissa, Priyanka, and other women who experience motherhood all discussed the ways that academic and professional environments both during and following graduate school were hostile or exclusionary toward pregnant people, particularly and almost exclusively pregnant cisgender women[1] and cisgender mothers. Melissa, for example, described how she felt pressured by her advisor, lab supervisor, and labmates to always be working, even when pregnant:

> When I was pregnant and needing to not work as long of hours, nobody had told me I had to work the long hours, except for maybe some postdocs, but there was a lot of pressure too. That made me feel like everything else is secondary to getting the papers out and getting the research done.

Even participants who had otherwise supportive relationships with their advisors reported receiving gendered microaggressions from faculty related to parenting. This further illuminates the complicated individual experiences of minoritized people who might experience support and discouragement simultaneously from one person. Kerry, for example, described a time when her advisor flagrantly misunderstood how reproductive anatomy functions, and in doing so implied that (cisgender) women should wait to

[1]We recognize and affirm that not only women can biologically rear children, and that one's ability to give birth is not a defining or determining factor of their gender. This said, all of the participants who referenced observing or receiving microaggressions regarding pregnancy identified as cisgender women and described these microaggressions as always being directed toward other cisgender women. As such, our language here is gendered to reflect the uniquely gendered nature of these microaggressions as shared by participants but should not be interpreted as supporting or agreeing with the bioessentialist conflation of gender and sex.

have children until post-tenure if they are in the academic profession:

> When I first told him that I wanted to have kids, he was like, "you should wait till you're tenured." And I'm like, "you know, I'm 27 and there are some biological limitations, and I'm not really willing to wait until I'm 40 to see if I can still have kids at that point. I'm glad that was an option for you."

Even though Kerry's advisor ended up being supportive in many ways that directly retained her in her doctoral program, these comments and more made Kerry feel uncomfortable or scared initially turning to her advisor when she was experiencing emotional distress, or when she actually became pregnant during her program, demonstrating the ways that even when unintentional, misogynistic microaggressions leave a lasting impact on doctoral students' understanding of their place in physics and astronomy. Sexual harassment and prenatal discrimination represent two of the myriad ways women doctoral students in physics and astronomy describe experiencing misogyny during graduate school. They also offered an opportunity for faculty and other stakeholders to disrupt the hegemonic system, which they unfortunately did not in many of the cases discussed here.

Racialized aggressions were also present for a few of the participants in pursuit of their graduate education. It is important to note that, as the stories from Da'Vonne, Stella, and others presented in the previous section allude to, Women of Color participants often reported experiences of racialized misogyny. Racialized aggressions frustratingly manifested mostly in the form of racialized misogyny, as the majority of Participants of Color in the sample also identified as women. As one of the only Women of Color in her department, Stella frequently named throughout her interview that the white women in her department were actively more antagonistic toward her than white men. This realization surprised her during her first few years in graduate school, as she assumed that she might be able to find solidarity with the few other women in the department, particularly the department's only woman faculty member. Of the many traumatizing stories Stella recounted of her interactions with this faculty member, one of the most troubling was when she discussed how another Latina student in the department was discouraged from continuing in the program when she did not pass a particular milestone without being given another opportunity to do so. The white woman professor used a pop culture metaphor to tell the Latina student she should not continue: "This is American Idol, and I'm Simon Cowell, and it would be a disservice to you if I told you that you could sing when you're just not cut out." Stella also shared negative interactions she had with a white woman student peer who yelled at her during a discussion of white privilege; this interaction happened at a conference intended to be "inclusive." Again, we see faculty enforcing a discriminatory problematic culture instead of trying to disrupt those narratives and support students in developing their agency and funds of identity. Had, for example, Stella's experiences and worldviews as a Woman of Color been respected by her white peers and faculty, as opposed to being vitriolically rebuffed for calling attention to issues like the normative whiteness that operates in many physics and astronomy spaces, the conferences, and classrooms she engaged as a graduate student might have been spaces that affirmed her identities by allowing Stella space to center her identities as they relate to physics and astronomy.

Queerphobia, discrimination against LGBTQ+ persons, was also apparent in the graduate school stories of participants who identify as queer and/or trans. It manifested both in informal interactions and professional settings, causing participants to change their behaviors and even avoid going to the office entirely. Kacey described being in a lab where the people were "very intensely religious" and whom she hid her same-sex relationship from at the request of her partner. When she got into a new relationship she was suddenly out and she described "being suddenly cornered" about her identity. After she began avoiding her on-campus office entirely. Paolo similarly encountered queerphobia when discussing policies banning LGBTQ+ people from serving in the military. In that conversation he felt that he had to "make a statement very crossly from the other side of the room" since the antagonist was being "loud" he "could be equally loud," simply responding by saying "Alexander the Great conquered half the world while [lewd description of engaging in male same-sex relationships], so I don't think that being queer and in the military has any drawbacks. She did not bring the subject back up again." No matter the modality of aggression, the omnipresence of gendered, sexual, and racialized forms of domination within the quotidian interactions participants had with other members of their departments holding majoritarian identities paints a troubling yet unsurprising picture of how identity is silenced and disregarded in the fiber of most physics and astronomy graduate programs. However, we see resistance in this story as he was able to write a new narrative and create new capital, by standing firm against discriminatory views.

Toxic faculty-student dynamics. Throughout the interviews, participants discussed their relationships with their graduate advisors and the multitude of challenges that arose in this dynamic. For some participants, there was discord between faculty expectations and the personal goals of participants. Such discord was apparent for Stella when she wanted to start planning her career with new professional development opportunities at her institution. Specifically, she wanted to take coursework on race but "didn't tell her advisor because [she] knew he would tell [her] not to do it." She further explained that she was receiving support from a career counselor on campus, but not her own department.

Stella explained that she was seen as a "troublemaker" and "had to choose her battles." Stella was concerned that if her advisor found out she might have had challenges getting him to sign off on other aspects of her program, such as allowing her to defend her dissertation. Through therapy, Stella learned, for herself, that her advisor was "a well-meaning white man" but "did not care for [her]." This made her coursework on race even more important because it became a "counterspace for [her]." These classrooms became places where she could learn the language about identity, systemic oppression, and the intersections of identity and domination needed to self-author her own narrative of how her experiences as a physics graduate student were largely exclusionary. In other words, to again use Wofford and Gutzwa's [35] language, Stella's courses on race and ethnic studies proved to be identity-affirming spaces that allowed her the ability to develop funds of her identity (in this case, the language needed to name and process the oppression she was actively experiencing in her physics department) to support her navigation of her graduate education. These oases of identity affirmation served as a respite from her home department, an environment that both actively and implicitly devalued her identity as a Woman of Color.

Stella's retelling of her graduate experiences was sadly far from the only to describe physics departments, and particularly the actions of faculty within these departments, as oppressive and toxic. Mateo felt that he was "held hostage" by his lab due to his financial ties to the funding his group provided. This limited his options in terms of switching advisors: he wasn't able to leave the lab until 3 years after this abuse began, even though he wanted to leave during his first year with the group. A compounding factor for him was his visa and ability to stay in the United States. His experience when he did decide to leave showed the toxic nature of his relationships: "When I decided to leave, […] they fired me, they yelled at me, they insulted me, and they kicked me out of the lab. It was horrible." Mateo later reflected on his experience by explaining that his advisors "traumatized" him and that, by the time he spoke with us, he had no continued relationship with any of them, only thinking of them when reflecting on how his current success demonstrated how he "made it in spite of them." Another example came from Felicia, who experienced a department chair trying to prevent her from graduating because he didn't see her work as "Ph.D. worthy" because she had not yet published "enough" peer-reviewed articles from the data she was working with. However, she described her work as taking over 500 hours, which to her "was something that was totally Ph.D. worthy." The self-described toxicity participants like Mateo and Felicia encountered as faculty tried to stalwart their progress toward their degree emerged as an example of how physics and astronomy departments function in ways that devalue, as opposed to affirming, minoritized students' identities, interests, and career trajectories.

Participants also discussed being pushed away from the potential of an academic career and realizing that just because someone shared experiences with them did not mean they would be an ally. In other words, having similar identities as other successful academics does mean they will use their success to help one another. Stella decided to leave the field after developing a disability that medical providers told her was "stress related." She wasn't able to get all the medical care she needed due to the cost of services and she further mentioned the difficulty of this decision because people who leave are viewed as "failures." Paul similarly began to feel like a failure when his advisor would leave for months at a time leaving him with little guidance to complete his work. He felt like a "failure" and found happiness through teaching as it was something he was "good at." Sam experienced strong discouragement from their advisor, to the point that they even kept a folder of the negative emails their advisor sent them:

> I had a folder full of emails […] called, "[Your Advisor] is Disappointed in You." It was a whole folder of emails of her telling me that I hadn't done enough, that she was disappointed in me, saying that over and over. And it really took a big toll on my mental health when I was in grad school and I wasn't really too enthusiastic about continuing in research.

While some were actively pushed out of research-leaning careers through toxic mentoring strategies, others decided to switch their career paths through observing the unhealthy workstyles tenure-track faculty normalized and implicitly expected students to adopt. In this way, they began to create their own story and learned from their previous experiences what they would not accept. Melissa, for example, described her advisor as showing her "all the things [she] didn't want to be" and realized through him that she did not have the "obsession" for research that he did:

> I think it's probably looking at what it was to be a hustling young faculty member. I saw a lot of those in graduate school, and just seeing the hours that they were always there, always obsessing or thinking about their projects—it is a zero-sum game. If you're there, then you're not somewhere else. And for me, I didn't wanna take my kids to daycare for 10 hours a day.

Similarly discussing the misalignment of faculty expectations and student goals, Phoebe discussed the reticence to change that faculty in her program expressed. She mentioned that "faculty were forever, and they're really good at reverting back." She said that she made the "decision that I'm gonna try to do work that I don't think is actively evil" by leaving the academy and that she did not want to have a job that weighed on her "like the last two years" of her

graduate program. A lack of willingness of program faculty to change their own behavior, as well as their expectations of their students, contributed to many participants' decisions to leave academic careers after completing their degrees and instead take employment in private or governmental sectors that they felt would be a less traumatizing career path that was more in line with their personal ideals. In this way, faculty refused to address underlying cultural beliefs and practices that negatively impacted students' inclusion within their discipline. This refusal indicates that faculty are often unwilling to (or at the very least unaware of the need to) create spaces that affirm students' identities within their classes, labs, and other environments.

Learning that faculty with similar experiences would not necessarily be good allies was a lesson learned by some participants as they completed their graduate programs. As one of the only women, let alone Women of Color, in her program, Stella thought she would find an ally in a white gay man professor. Sadly, she shared that this faculty member ultimately "turned out to be one of my biggest literal enemies," as he would talk negatively about her in their small department even though she only had one class with him and was not in his research group. Stella was further impacted when the first female faculty member in their department took credit for an idea she presented to her —a story that we will unpack in discussing findings related to our second research question—and then later accused Stella of cheating.

Finally, the location of the graduate program was also a challenge for some participants, including Juan. Juan felt he had to "sacrifice" to live in a rural town even when the program itself was a positive experience. Even though Juan never experienced hostility from peers or professors, the perceived lack of safety he felt in the surrounding community of his graduate program actively shaped his decision to take a postdoctoral position located at a nationally renowned museum as opposed to at a university mainly because the museum was located in a liberal-leaning urban metropolitan city that he felt safe living in as a queer Man of Color; Juan noted that during his time on the job market, jobs at universities in similar metropolitan locations were difficult to find in his subfield. Stories like Juan's further suggest that the challenges faced by minoritized communities in physics and astronomy move beyond just the department dynamics. In totality, the participants describe an environment that can be challenging to navigate, while developing one's own productive funds of identity. Though some did choose to leave, others were able to build their own internalized capital to help them find success.

B. Research question II: How did participants build and utilize their social networks to navigate these departmental climates?

When describing their social networks, participants identified three main categories of people that supported their navigation of the exclusionary environments of their doctoral programs: peers; faculty allies; and identity-based affinity groups. These series of interpersonal interactions with individual allies and in larger communal settings are indicative of the ways individual- and institutional-level dimensions can be constructed to support physics and astronomy students holding minoritized identities [35]. Individual interactions with supportive peers and faculty oftentimes were avenues where participants found that individual actors within the departmental structure supported their abilities to leverage their lived experiences to build their science identities in ways that could coexist with their minoritized social identities. Affinity groups similarly functioned as identity-affirming spaces that helped participants navigate, process, and in some cases subvert departmental-level dimensions of oppression that they encountered as minoritized students. Through individual interactions and existing in spaces that affirmed their identities, participants were able to intentionally create social networks that facilitated their ability to resist the disciplinary-level dimensions of power and subjugation that perpetuate the minoritization that underrepresented communities in physics and astronomy disciplines often encounter.

1. Support from peers

One of the largest ways participants navigated departmental exclusion was by building community with peers in their departments. Whether these peers shared participants' identities, held similar identities, or were allies, finding collegiality and colleagueship among fellow students who affirmed participants' identities and experiences proved invaluable for many. Many participants described how building connections with peers in their program helped them navigate the procedural elements of their programs and their job application processes for their first positions following graduate school. Describing the connections he made in his department's graduate student group, Ethan explained:

> It was mostly just friendship as support, everything that comes along with that emotional support. People who are further along in their programs providing advice about, at different stages, what should you be doing or thinking about, or how should you be approaching your grad school trajectory.

One additional modality of support peers provided participants was to help them make sense of and navigate toxic tensions within their departments, particularly those stemming from relationships with faculty. Felicia described how living with three of the other graduate students in her program helped her process tensions:

> I was very honest with how I was feeling to them, and they were very honest back. There were lots

> of little things going on internally and we all talked about it. … the particularly toxic professor who kind of threatened to make sure I couldn't graduate, … they all had very similar experiences, so it was something that the graduate students would talk to each other about.

Phoebe turned to peers she met in an informal STEM graduate student group to process the toxic tensions in her department. She, in particular, explained how the fact that the students, many of whom were more advanced in their programs than Phoebe was, "were maybe less fired up about things because they had kind of already entered the tempered, jaded phase, they were [still] really critical for me." Through peer support, the students leveraged their relationships to disrupt systemic issues of cultural acceptance of bad behavior and problematic professional interactions. In this vein, the students helped one another to rewrite the future of their disciplinary context by refusing to ignore and accept the conditions faced by minoritized students, even if they had no formal role to push back. Still, many more students found support through more formalized identity-based affinity groups, wherein they were able to make deeper connections with other peers who held similar social identities as they did; we will discuss these experiences more in-depth in the following sections. These types of group interactions served as counterspaces [2] that helped participants develop their funds of science identity by developing communities and networks that affirmed their identities and their experiences of identity-based oppression within hegemonic, othering physics and astronomy departments.

Particularly for participants who identify as transgender or nonbinary, like Sequoia, and those who identify as Women of Color, like Stella, even with some degree of peer support, some participants still expressed feelings of isolation and discomfort in discussing toxic departmental tensions with peers. Reflecting on relationships they developed with two of their peers, Sequoia mentioned how while their perspectives and solidarity were supportive, they still felt isolated navigating academic and identity-based isolation in their department:

> There were two grad students who I felt like were grappling with it similarly. [One] was also minoring in women and gender studies, which helped give us a fun new perspective to the conversation. But it was a lot of grappling alone. I felt like I just was kind of weird about it for a really long time.

Navigating a department with a terse, racially charged climate as a Woman of Color, Stella had few Peers of Color she was able to turn to. The overwhelming whiteness of the space moderated not just who she experienced racialized aggression from, but also those who helped her navigate said tension: "It was mostly white people in my department, so the majority of my foes were white, but also the majority of the people who were supporting me were also white." While some white individuals who offered support were faculty—stories that will be explored in the next section—white men peers also provided Stella some space to gain mentorship and support. Intersections of minoritization and heightened invisibility of peers holding similar social identities shaped many participants' needs to find allyship with those holding majoritarian social identities but also contributed to the continued isolation many felt after such allyship was built. This reality complicated the disruption of systemic issues, as well as the rewriting of future disciplinary contexts, suggesting that the development of one's capital through having space to build their funds of science identity is not a linear path. Instead, it may move forward and backward, demonstrating that many of these participants continually negotiate the reality of their toxic environments even while building ever stronger navigational capital.

2. Support from faculty

Faculty were an additional source of support for some participants as they navigated their doctoral programs. The majority of participants who spoke of the support faculty provided them referenced such support as it related to their navigation of their career trajectories. Faculty are critical in their potential role of disrupting toxic norms within the physical sciences, to help guide students to their own development of internal capital, even if imperfect in this process. Some participants described faculty advisors as people who tried to understand and work with participants' personal and professional goals, treating their advisees as humans above just employees in a lab. Janelle, for example, reflected positively on her relationship with her advisor: "she was always like, 'where do you want to go and where do you wanna be?' I always felt supported by her no matter what I said." Da'Vonne similarly reflected on how her advisor's support of her interests was powerful in developing her academic and professional sense of self:

> I was able to do the work I wanted to do, not the work he wanted me to do. Even if it was a situation where I had to, he was like, "We're gonna find a way to get you back to what you wanna do."

Da'Vonne and Janelle's descriptions of their advisors' approaches to mentorship are polar opposites of the cold, exclusionary, and often damaging approaches described by other participants (for example, Mateo's advisors' attempts to "hold him hostage" to their lab, as shared earlier in this article). By prioritizing the needs, interests, and desires of their students as opposed to their own, these faculty constructed relationships with their students that directly affirmed their identities, relying on the funds of science

identity that their advisees developed throughout their lives to guide their approach to mentorship and in turn recognizing that not all students share the same concerns, needs, and professional goals.

Da'Vonne and Priyanka both attributed their advising and mentoring practice—regardless of whether or not they entered faculty or other academic careers—as being directly informed by positive interactions they had with faculty mentors during graduate school. Showing how their faculty's actions rewrote the narrative of a possible future in the physical sciences for these participants. Which may have supported in them individually building their own funds of science identity to further reify their own internal capital. These stories contrast with those shared by many participants in the prior section, who reported that faculty served as antipossibility models or examples of the type of professional they did *not* want to become. Da'Vonne described a desire to "be what I want" as a mentor, highlighting her experiences with her faculty advisor as shaping the ways she approaches mentorship with care, compassion, and unwavering belief in those she supports: "the compassionate type of mentorship, the mentorship that is allowing you to be the full person [in] what you're doing, it's what I try to be." Priyanka was unable to find women faculty within her own program to confide in as mentors and thus sought other women faculty across campus:

> I was just looking for a woman, and there she was. I really looked up to her because she had two kids, and she used to manage this whole work-life thing, and she didn't really care what anybody else thought, and she did really well. I think mostly because maybe she didn't care. She seemed a little immune to a lot of things.

Holding space for earlier career woman colleagues in her current workplace is a core value of Priyanka's professional praxis, as are many of the ways she has decided to navigate professional life as a working mother and standing up for colleagues and employees in her workplace. Priyanka attributed many of these qualities to the "informal" mentorship she received from this woman faculty member during her time as a graduate student. These narratives corroborate much of what Wofford and Gutzwa [35] mean when they describe the potential for mentoring relationships to be identity-affirming spaces. Priyanka was able to develop funds of her science identity by intentionally seeking out mentorship and community with other women during her time as a graduate student. Not only did these funds of identity that she developed through these relationships help her navigate hostile and oppressive environments as a graduate student in physics, in turn becoming a form of navigational capital for herself, but they also have continued to shape her professional praxis by helping other women develop and utilize funds of *their own* identity in the workplace. These organic and constantly replicating iterations of identity-affirming mentorship, despite happening on more individual levels, are also examples of how prioritizing the funds of science identity minoritized students bring with them to their educational and professional environments can help disrupt generations of cyclical systemic oppression that occur at a disciplinary level in physics and astronomy fields [35].

The emotional support that faculty both explicitly and implicitly provided some participants also helped them navigate feelings of imposter syndrome. Da'Vonne described how her advisor's unwavering faith in her abilities circumvented feelings of imposter syndrome and supported the development of her funds of science identity:

> Never once did he ever doubt my ability to do anything. … It was fascinating to me. I believed I could do it because he would literally say it out loud, before he even *knew* me. I was like, "Ah, I guess I really can do this thing." This guy thinks I can.

For some, this type of support and compassion was particularly salient as they grappled with the decision to not pursue academic- or research-facing careers. Velma, who experienced both self-described "burnout" and "imposter syndrome" during her graduate school experience, was able to find a level of solace in her advisor:

> I felt grateful for the patience he showed me. He wasn't mad at me, or telling me that I was bad at things. I was probably meaner to myself [than he was], and he wasn't, you know, trying to push me out of his group or something.

Kerry similarly reflected on her advisor's understanding and support as she navigated a particularly rough time for her mental health during graduate school, crediting him as the reason she completed her doctoral program in the first place:

> I had a really hard time when I was a third year Ph.D. student. … I ended up in therapy because I wasn't writing a paper that I needed to be writing, and kind of having a mental health crisis. I went to him really scared of how he was gonna respond, and told him what had been going on with me and how I was figuring out how to get my anxiety and depression under control. And he was like, "okay, so you have a blank slate now. You've explained to me what's going on. And I'm gonna give you another chance. And you don't get another chance moving forward, but this is your blank slate." And I don't think I would have stayed a Ph.D. student if that had not been his response at that time.

While extending grace and care to doctoral students sounds very much like a bare minimum of support, the frequent encounters with toxicity in faculty-student relationships that many participants described make these intermittent glimmers of humanistic, emotional support offered by faculty members all the more noteworthy.

While many participants experienced toxicity in their relationships with faculty in their programs, faculty also offered some participants allyship and support in navigating some of the distressing elements of their doctoral experiences. When multiple faculty members in Felicia's program tried to bar her from advancing and ultimately graduating based on a lack of understanding of the rigor and quality of her work, Felicia reflected on how other faculty members stepped in to provide guidance:

> One of the other professors who was somewhat familiar with my work was very positive. She said, "I'm just here to ask you if you're getting stuff done, and as long as you say yes, I am perfectly happy with your progress. If you say you're gonna get a paper published, I am happy to believe you." And even though my advisor wasn't [always] there, he was very supportive. He was never the greatest at actually helping with the research itself, but he was very great in preventing people who didn't want me to graduate, or had issues with me. [One] professor was in a fight threatening another student, [and] he threatened to make sure I couldn't graduate 'cause he was on my committee, unless I sided with him against this other student. … I got my advisor to remove him from my committee.

Similarly, when Stella was accused of cheating by the only woman faculty member in her department—itself a racialized aggression against Stella, a Woman of Color, at the hands of a white woman faculty member—she found that she was able to turn to "one senior professor who was very kind, very gentle" for advice:

> I would just close the door, and I would be like, "Can you talk about this anonymously at the faculty meeting?" And he would be like, "Okay, sure." And he would always do that. … when that professor accused me of cheating, I went to him and I was like, "What do I do?" Because I was like, "I know this is not true, I'm afraid of what's gonna happen if this gets around." And so that professor I could usually count on.

In both Felicia and Stella's experiences, it is important to note that some of the faculty mentors they reference were still not ones they wholly felt comfortable turning to for all of the problems they encountered during their programs. They each could provide a component of support but were individually able to disrupt the toxic challenges they faced. As Felicia mentioned, for example, her faculty advisor was not helpful or supportive in the way of helping advance Felicia's research, so many gaps were still present in the ways she was able to navigate tense academic environments in her program and advance toward graduation; on the other hand, Stella described the "kind" and "gentle" senior professor as someone who she "would never really go to if I was feeling particularly emotional," only turning to him when there was "something that had to get resolved," like the accusations of cheating levied against her by another faculty member. Still, the relative support both felt in turning to faculty in their programs for various forms of navigational support is reflective of how many participants described the role of faculty in helping them the capital to navigate toxic environments in their graduate programs.

3. Support from identity-based affinity groups

One commonality across many participants' narratives was the relative absence of identity-based affinity groups within their departments. Many were forced to find such spaces elsewhere on campus or found these groups themselves. Crediting graduate Student of Color groups at her university as responsible for "how [she] got through grad school," Da'Vonne described her navigational strategy for coping with her department's lack of other Black students as "search[ing] for the non-white people. 'Okay, there's a BSA, go in there.' 'Alright, there's something Brown over there, let's go there.' " Kacey similarly described how founding an LGBTQ+ group in her department, while laborious, was instrumental to her success in navigating exclusionary program climates, showing how she individually built up her on funds of science identity:

> I put a lot of energy into building communities, and I think that that was critical to me getting through all of this. But […] it was a lot of energy to build this stuff. […] I was unhappy, and then at some point I found one person, and then I tried to build up stuff around me. I think sometimes, if I hadn't taken the initiative, I worry I wouldn't have found my people.

Da'Vonne and Kacey's experiences also underscore how minoritized students are routinely unsupported by physics and astronomy departments in building community vital to developing this form of capital: both were forced to develop capital that helped them navigate toxic physics and astronomy environments through founding and/or participating in identity-based groups. Such efforts may also have systemic positive impacts, supporting the creation of new pathways in their given fields.

It is important to not romanticize identity-based groups as universally supportive. Sam and Phoebe, for example, both shared that they stopped attending women in STEM

groups in graduate school after meetings reinforced heteronormative assumptions of the "challenges" women might face in the academy: "The first one I went to, the Dean of Sciences said '[this university]'s really great because it's really easy to have a child here.' This cannot be the number one issue for women today" (Phoebe). While not supportive, women's groups helped participants like Phoebe indirectly develop navigational capital by illuminating how some institutionally-created spaces might sound nominally supportive but fail to do so in praxis.

Further, some participants experienced hostility or other modes of domination when attempting to build affinity groups. Stella, a Latina Woman of Color, experienced racialized and gendered tensions when trying to build a women in STEM lunch group in her department. Attempting to work with the department's only woman faculty member (a white woman—and also the same faculty member who ultimately accused Stella of cheating later on in her doctoral program), she talked openly about her desire to create a counterspace for women, partly in an attempt to build "good rapport with her." After Stella's conversation with this faculty member, the lunch group came to fruition—but not how Stella had hoped or intended:

> A couple of weeks later, I see that she announced to the department that she was gonna start this Women in Physics lunch. She took credit for my idea. But then also, the environment was not allowed to be a women-only space, and so then there were men who joined and took over the conversations, so it was not at all what I envisioned. I was really disappointed in that.

Similarly to how other scholars have described the co-opting of diversity, equity, and inclusion work by white women in STEM spaces [56], Stella's experience of a white woman faculty member usurping Stella's ideas to create a women's group for sociopolitical clout within the department reflects the pernicious ways white involvement in diversity, equity, and inclusion work can often perpetuate racism in light of advancing (white) gender equity. Nuances in the experiences of Phoebe, Stella, and others remind that identity-based affinity groups do not wholly serve as liberatory spaces, especially at the intersections of gender, race, and other minoritized identities. However, they can also be one way to construct a person's funds of science identity to give them the internalized capital they need to navigate the challenging environment of the physical sciences.

V. DISCUSSION AND IMPLICATIONS

Findings demonstrate that minoritized doctoral students in physics and astronomy are forced to develop their own navigational strategies to survive in exclusionary departments and institutions. Identity neutrality as a normative value of physics and astronomy graduate education perpetuates the deficit-based understandings of minoritized students in STEM postsecondary education [33,35] by insinuating that exclusion and domination are figments of students' imaginations that departments have no responsibility to address. We argue that by viewing students' identities as assets to their success, it is possible to amplify minoritized students' existing capital and help them develop capital by facilitating the creation of their social networks and celebrating the intersections of their social and "science" identities. Department-, institutional-, and discipline-level reform that truly subverts the systems of domination that perpetuate inequity in physics and astronomy necessitates the transformation of physics, astronomy, and related doctoral programs into identity-affirming spaces [16,35]. In this section, we illuminate how findings answering the first research question can inform understanding of how participants developed funds of science identity during their doctoral programs that they then used as navigational capital in circumventing exclusion on a department level, as demonstrated through the findings that answer our second research question. This conversation is also integrated with a discussion of implications for research and practice that can actualize disrupting systemic inequity as perpetuated by and ingrained in STEM postsecondary education.

In holding space for the at best neutral and at worst traumatizing experiences participants shared about their time in their doctoral programs, we intentionally avoid implicitly rooting the experiences of minoritized physics and astronomy doctoral students solely in the trauma that many participants encountered; as Nicolazzo [57] reminds in discussing tenets of trans* epistemologies, the narratives of minoritized communities may come *from* trauma, but minoritized groups are not themselves *of* trauma. In balancing the desire to reflect participants' lived realities authentically with the desire to view participants through asset-based lenses, the funds of science identity framework shapes our understanding of how experiences of exclusion within departments of physics and astronomy informed the embodied epistemologies participants drew on to navigate and overcome said exclusion.

As alarming as the numbers are to read—that 96% of participants reported neutral at best and wholly negative at worst experiences in their doctoral programs—the reality of the situation is that these numbers are neither surprising nor unfathomable. The nuanced ways that doctoral programs traumatized many participants through toxic cultures and interactions with peers, faculty, and institutions is a plain reminder of how physics and astronomy doctoral programs do not operate, in many instances, as identity-affirming spaces. As the findings demonstrate, many participants were explicitly and implicitly told that their minoritized gender, racial, and/or sexual identities had no place in physics and astronomy as fields, let alone within the

classrooms and other research spaces they engaged in throughout their doctoral journeys. Others came to this realization through watching others navigate oppressive systems (like Priyanka's retelling of a woman being failed by her department after coming forward with allegations of sexual harassment), or through learning what they themselves did not want to become after witnessing the ways faculty work, mentor, and (fail to) support fellow graduate students. In each of these instances, physics and astronomy departments might have been places where students developed funds of science identity, but they also remained spaces where such funds of participants' identities were devalued, underappreciated, and wholly unsupported.

Findings simultaneously corroborate and complicate much of what has been explored in STEM education literature broadly and documented more explicitly in physics and astronomy education literature: arguments that a lack of representation of students and faculty who share individuals' identities signals the lack of inclusivity of a department [58] and that counterspaces created by and for multiply minoritized communities are one necessary step in countering the gendered racism ingrained within STEM departments [2,56]. Findings also demonstrate the ways that minoritized populations in physics and astronomy are still frequently understood by faculty and departments through deficit-based lenses. From the advice given to Kerry that women should wait to have children until after tenure so that their academic progress is not inhibited, to the framing of women's issues as solely revolving around pregnancy that participants like Phoebe experienced in women in STEM spaces, much of this deficit-based thinking is still rooted in the ways that physics and astronomy are built on gendered and exclusionary misogynistic cultures [22]. Stella's experiences navigating cheating allegations and the co-opting of ideas by white women faculty and the observations of participants like Priyanka and Da'Vonne that People of Color—namely Women of Color—were almost always absent from STEM departments and, oftentimes, graduate campuses generally demonstrate in real time the gendered racism that STEM departments often foist onto Women of Color [20], and the ways that racism permeates faculty understandings of who can be successful in STEM disciplines [33].

Future research must continue to take critical approaches to understanding inequity and systemic oppression as they manifest within and are perpetuated by STEM departments. In doing so, qualitative work that intentionally gets at the intersecting identities minoritized communities hold and the ways that interlocking matrices of domination [49] persist *through* unreformed STEM departments must continue to be undertaken by equity-minded researchers in STEM postsecondary education. As aforementioned, scholars have long reinforced a monolithic understanding of underrepresentation in STEM by implying that gender inequities in STEM education are binary in nature by only prioritizing the lack of (white) women represented in STEM departments [14,59], inadvertently silencing queer and trans communities as well as Women of Color in doing so. While this study's aim focused largely on gender and sexuality minoritization in physics and astronomy, findings from this study contribute to a growing (yet still stagnant) body of literature interrogating minoritization through its intersections, giving voice to the realities of trans, nonbinary, and Communities of Color who are most often forgotten in STEM research. To this aim, future work must continue to more explicitly and actively center multiply minoritized narratives by extending beyond sample populations that also can include cisgender, heterosexual, white women.

Participants' funds of science identity were also employed as they navigated exclusionary environments, particularly informing how participants built social networks to act as collectives of resistance against the oppression they encountered daily through the fabrics of their doctoral programs. Reading these experiences through a lens of navigational capital [34] illuminates that participants' construction of social networks was an agential process. Again, it is important to not romanticize the resilience demonstrated by participants as wholly liberatory as doing so runs the risk of glamorizing experiences of trauma and implying that institutions do not need to change in the event that students can still thrive and navigate without wider reform [40,41]. Still, the collective organizing of social networks demonstrated by participants highlights the ways that counterspaces, allyship, and collective organizing around issues of identity both *can* and *does* happen within even the most "identity-neutral" spaces to transform the experiences of multiply minoritized students. Findings demonstrate a need for more work exploring experiences of minoritization through a social network analysis lens, as doing so holds the power to understand student experiences through more nuanced and asset-based mentalities.

At the same time, the individual nature of participants' narratives demonstrates the range of experiences and realities that complicate the effectiveness *of* certain initiatives and spaces. The range of discrepancies between how participants made sense of their experiences in identity-based affinity groups, for example, demonstrates that simply recommending that departments should create more identity-based support groups for students might have more of a detrimental effect than intended. As others have problematized, many STEM departments have historically responded to concerns of diversity, equity, and inclusion by throwing money at the problem to send students to off-campus diversity conferences instead of also directing resources internally to address systemic minoritization within the context of the department [2,56]; while Stella's experience demonstrates such spaces can be liberatory, Phoebe's experiences with similar types of

programming demonstrate the limited range of utility such spaces might often present. As such, STEM education research and practice should move away from working to highlight a list of universal best practices, as such efforts will always continue to privilege the most majoritarian of the minoritized populations these events intend to cover [40,41].

Policy and practice must also additionally consider people, and specifically Women, of Color when doing this work. In our study, their challenges of being women and/or LGBTQ+ were amplified by the additional challenges of being a minoritized ethnicity or race in physics. This may necessitate a stronger need to build funds of identity. The building of funds of identity proposed here strongly aligns with the Black physics Identity work by Hyater-Adams *et al.* [60] for these participants. As we argue that participants need to build their own funds of identity as a resource to persevere, Hyater-Adams explains the needs of Black physicists to develop resources (relational, ideational, and material). Both of our works highlight the importance of recognizing the need to do this for the populations discussed. They also demonstrate the need to understand the full identities of persons being studied and to never discount intersecting realities, especially race.

A more nuanced approach to policy recommendations is one way to mitigate these concerns. Funds of knowledge-informed frameworks have been used to inform policy decisions at institutional, local, regional, and national levels in the field of education [41]; our use of the funds of science identity framework follows in the same intellectual genealogy. Findings demonstrate clear ways where toxic workplace environments, an overemphasis on idealized identity neutrality, and more myopic- and macrolevel power imbalances manifest in ways that exclude and silence minoritized communities. Future research taking a funds of science identity approach to understand the experiences of minoritized people in STEM disciplines through asset-based lenses should continue to expose areas where simple, vague "nondiscrimination" policies are not enough to prevent furthering the harm LGBTQ+ scientists, disabled people, People of Color, and more minoritized communities experience daily. By intentionally integrating practice and research with the understanding that students are individuals before they form a collective population, it becomes possible to understand and subsequently address the myriad forms of systemic domination that STEM programs and professional disciplinary workspaces perpetuate [35].

ACKNOWLEDGMENTS

The authors would like to thank the study participants and the National Science Foundation for funding this work (No. 2054920, No. 2055237, and No. 2100024).

[1] R. E. Friedensen, E. Kimball, A. Vaccaro, R. A. Miller, and R. Forester, Queer science: Temporality and futurity for queer students in STEM, Time Soc. **30**, 332 (2021).

[2] T. M. Nakajima, J. R. Karpicz, and J. A. Gutzwa, "Why isn't this space more inclusive?": Marginalization of racial equity work in undergraduate computing departments, J. Diversity Higher Educ. **17**, 27 (2024).

[3] R. S. Barthelemy, C. Henderson, and M. L. Grunert, How do they get here?: Paths into physics education research, Phys. Rev. ST Phys. Educ. Res. **9**, 020107 (2013).

[4] B. Van Dusen, R. S. Barthelemy, and C. Henderson, Educational trajectories of graduate students in physics education research, Phys. Rev. ST Phys. Educ. Res. **10**, 020106 (2014).

[5] R. S. Barthelemy, B. Van Dusen, and C. Henderson, Physics education research: A research subfield of physics with gender parity, Phys. Rev. ST Phys. Educ. Res. **11**, 020107 (2015).

[6] American Physical Society, Bachelor's degrees in physics and STEM, http://www.aps.org/programs/education/statistics/bachelors.cfm.

[7] M. Rodriguez, R. Barthelemy, and M. McCormick, Critical race and feminist standpoint theories in physics education research: A historical review and potential applications, Phys. Rev. Phys. Educ. Res. **18**, 013101 (2022).

[8] L. M. Aycock, Z. Hazari, E. Brewe, K. B. H. Clancy, T. Hodapp, and R. M. Goertzen, Sexual harassment reported by undergraduate female physicists, Phys. Rev. Phys. Educ. Res. **15**, 010121 (2019).

[9] R. S. Barthelemy, M. McCormick, C. R. Henderson, and A. Knaub, Educational supports and career goals of five women in a graduate astronomy program, Phys. Rev. Phys. Educ. Res. **16**, 010119 (2020).

[10] R. S. Barthelemy, M. McCormick, and C. R. Henderson, Understanding women's gendered experiences in physics and astronomy through microaggressions, presented at PER Conf. 2014, Minneapolis, MN, 10.1119/perc.2014.pr.005.

[11] R. Barthelemy, M. McCormick, and C. Henderson, Barriers beyond equity: An exploratory study of women graduate students' career pathways in astronomy, Int. J. Gender Sci. Technol. **7**, 57 (2015), https://genderandset.open.ac.uk/index.php/genderandset/article/view/371.

[12] R. S. Barthelemy, M. L. Grunert, and C. R. Henderson, The graduate research field choice of women in academic physics and astronomy: A pilot study, AIP Conf. Proc. **1513**, 66 (2013).

[13] M. McCormick, R. Barthelemy, and C. Henderson, Women's persistence into graduate astronomy programs: The roles of support, interest, and capital, J. Women Minorities Sci. Eng. **20**, 317 (2014).

[14] L. J. Sax, M. A. Kanny, T. A. Riggers-Piehl, H. Whang, and L. N. Paulson, "But I'm not good at math": The changing salience of mathematical self-concept in shaping women's and men's STEM aspirations, Res. High. Educ. **56**, 813 (2015).

[15] TEAM-UP, *The Time Is Now: Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy* (American Institute of Physics, College Park, MD, 2020).

[16] R. S. Barthelemy, B. E. Hughes, M. Swirtz, M. Mikota, and T. J. Atherton, Workplace climate for LGBT+ physicists: A view from students and professional physicists, Phys. Rev. Phys. Educ. Res. **18**, 010147 (2022).

[17] E. V. Patridge, R. Barthelemy, and S. R. Rankin, Factors impacting the academic climate for LGBQ STEM faculty, J. Women Minorities Sci. Eng. **20**, 75 (2014).

[18] M. McCormick and R. S. Barthelemy, Excluded from "inclusive" communities: LGBTQ youths' perception of "their" community, J. Gay Lesbian Soc. Serv. **33**, 103 (2021).

[19] R. S. Barthelemy, M. Swirtz, S. Garmon, E. H. Simmons, K. Reeves, M. L. Falk, W. Deconinck, E. A. Long, and T. J. Atherton, LGBT+ physicists: Harassment, persistence, and uneven support, Phys. Rev. Phys. Educ. Res. **18**, 010124 (2022).

[20] E. M. Schipull, X. R. Quichocho, and E. W. Close, "Success Together": Physics departmental practices supporting LGBTQ+ women and Women of Color, presented at PER Conf. 2020, Provo, UT, 10.1119/perc.2019.pr.Schipull.

[21] X. R. Quichocho, E. M. Schipull, and E. W. Close, Understanding physics identity development through the identity performances of Black, Indigenous, and Women of Color and LGBTQ + LGBT+ women in physics, presented at PER Conf. 2020, virtual conference, 10.1119/perc.2020.pr.Quichocho.

[22] R. S. Barthelemy, M. McCormick, and C. Henderson, Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions, Phys. Rev. Phys. Educ. Res. **12**, 020119 (2016).

[23] R. S. Barthelemy, A. L. Traxler, J. Blue, and M. G. Swirtz, Research on gender, intersectionality, and LGBTQ+ persons in physics education research, in *The International Handbook of Physics Education Research: Special Topics*, edited by M. F. Taşar and P. R. L. Heron (AIP Publishing LLC, Melville, NY, 2023).

[24] A. T. Danielsson, Exploring woman university physics students 'doing gender' and 'doing physics,', Gender Educ. **24**, 25 (2012).

[25] A. J. Gonsalves, Gender, and doctoral physics education: Are we asking the right questions?, in *Doctoral Education: Research-Based Strategies for Doctoral Students, Supervisors, and Administrators*, edited by L. McAlpine and C. Amundsen (Springer Netherlands, Dordrecht, 2011), pp. 117–132.

[26] A. J. Gonsalves, Exploring how gender figures the identity trajectories of two doctoral students in observational astrophysics, Phys. Rev. Phys. Educ. Res. **14**, 010146 (2018).

[27] N. J. Mikkelsen, N. T. Young, and M. D. Caballero, Investigating institutional influence on graduate program admissions by modeling physics graduate record examination cutoff scores, Phys. Rev. Phys. Educ. Res. **17**, 010109 (2021).

[28] A. J. Gonsalves, "Physics and the girly girl—There is a contradiction somewhere": Doctoral students' positioning around discourses of gender and competence in physics, Cult. Stud. Sci. Educ. **9**, 503 (2014).

[29] R. S. Barthelemy, LGBT+ physicists qualitative experiences of exclusionary behavior and harassment, Eur. J. Phys. **41**, 065703 (2020).

[30] T. J. Atherton, R. S. Barthelemy, W. Deconinck, M. L. Falk, S. Garmon, E. Long, M. Plisch, E. H. Simmons, and K. Reeves, *LGBT Climate in Physics: Building an Inclusive Community* (American Physical Society, College Park, MD, 2016).

[31] S. Traweek, *Beamtimes and Lifetimes: The World of High Energy Physicists* (Harvard University Press, Cambridge, MA, 1988).

[32] B. Subramaniam, Cartographies for feminist STS: Celebrating the work of Sharon Traweek, Engaging Sci. Technol. Soc. **7**, 65 (2021).

[33] S. R. Harper, An anti-deficit achievement framework for research on Students of Color in STEM, New Dir. Inst. Res. **2010**, 63 (2010).

[34] T. J. Yosso, Whose culture has capital? A critical race theory discussion of community cultural wealth, Race Ethn. Educ. **8**, 69 (2005).

[35] A. M. Wofford and J. A. Gutzwa, Funds of science identity: Toward an asset-based framework for undergraduate STEM research and praxis, J. Women Minorities Sci. Eng. **28**, 59 (2022).

[36] L. Avraamidou, Science identity as a landscape of becoming: Rethinking recognition and emotions through an intersectionality lens, Cult. Stud. Sci. Educ. **15**, 323 (2020).

[37] C. Convertino, Nuancing the discourse of underrepresentation: A feminist post-structural analysis of gender inequality in computer science education in the US, Gender Educ. **32**, 594 (2020).

[38] M. Esteban-Guitart, Towards a multimethodological approach to identification of funds of identity, small stories and master narratives, Narrative Inquiry **22**, 173 (2012).

[39] M. Esteban-Guitart, *Funds of Identity: Connecting Meaningful Learning Experiences In and Out of School* (Cambridge University Press, Cambridge, England, 2016).

[40] J. A. Gutzwa, "It's not worth me being who I am": Exploring How Trans* collegians navigate classroom experiences through a funds of identity lens, J. Women Gender Higher Educ. **14**, 302 (2021).

[41] J. A. Gutzwa, Trans* funds of identity: exploring trans* collegians' classroom experiences to envision anti-oppressive education, Ph.D. thesis, University of California, LA, 2022.

[42] J. Antonellis, Third space for cultural relevance and conceptual understanding in the tribal college science classroom, Mellon Tribal Coll. Res. J. **1**, 77 (2013).

[43] D. Verdín, A. Godwin, and B. Capobianco, Systematic review of the funds of knowledge framework in STEM education, in *Proceedings of 2016 ASEE Annual Conference & Exposition* (New Orleans, LA, 2016).

[44] M. A. Maher, A. M. Wofford, J. Roksa, and D. F. Feldon, Exploring early exits: Doctoral attrition in the biomedical sciences, J. Coll. Student Retention **22**, 205 (2020).

[45] A. M. Wofford, Modeling the pathways to self-confidence for Graduate School in Computing, Res Higher Educ. **62**, 359 (2021).

[46] A. Marin and B. Wellman, Social network analysis: An introduction, in *The SAGE Handbook of Social Network Analysis*, edited by J. Scott and P. J. Carrington (SAGE Publications, 2014).

[47] B. L. Perry, B. A. Pescosolido, and S. P. Borgatti, *Egocentric Network Analysis: Foundations, Methods, and Models* (Cambridge University Press, Cambridge, England, 2018).

[48] M. Misawa, Social justice narrative inquiry: A queer crit perspective, in *Adult Education Research Conference* (Saratoga Springs, NY, 2012).

[49] P. H. Collins, *Black feminist thought: Knowledge, consciousness, and the politics of empowerment* (Unwin Hyman, Boston, MA, 1990).

[50] C. Noy, Sampling knowledge: The hermeneutics of snowball sampling in qualitative research, Int. J. Social Research Methodology **11**, 327 (2008).

[51] I. Seidman, *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*, 3rd ed. (Teachers College Press, New York, 2006).

[52] B. Hollstein, Qualitative approaches, in *The SAGE Handbook of Social Network Analysis*, edited by J. Scott and P. J. Carrington (SAGE Publications, Thousand Oaks, CA, 2011), pp. 404–416.

[53] P. Tubaro, L. Ryan, and A. D'angelo, The visual sociogram in qualitative and mixed-methods research, Sociol. Res. Online **21**, 180 (2016).

[54] J. Saldaña, *The Coding Manual for Qualitative Researchers*, 4th ed. (SAGE Publications, Thousand Oaks, CA, 2021).

[55] M. Ong, Body projects of young Women of Color in physics: Intersections of gender, race, and science, Social Problems **52**, 593 (2005).

[56] J. R. Karpicz, T. M. Nakajima, and J. A. Gutzwa, Challenging normalized gendered racism in departmental efforts to broaden participation in computer science, J. Women Gender Higher (2024), 10.1080/26379112.2024.2373479.

[57] Z. Nicolazzo, Imagining a trans* epistemology: What liberation thinks like in postsecondary education, Urban Educ. **56**, 511 (2021).

[58] T. Nkrumah and K. A. Scott, Mentoring in STEM higher education: A synthesis of the literature to (re)present the excluded Women of Color, Int. J. STEM Educ. **9**, 50 (2022).

[59] L. J. Sax, K. J. Lehman, J. A. Jacobs, M. A. Kanny, G. Lim, L. Monje-Paulson, and H. B. Zimmerman, Anatomy of an enduring gender gap: The evolution of women's participation in computer science, J. Higher Educ. **88**, 258 (2017).

[60] S. Hyater-Adams, C. Fracchiolla, T. Williams, N. Finkelstein, and K. Hinko, Deconstructing black physics identity: Linking individual and social constructs using the critical physics identity framework, Phys. Rev. Phys. Educ. Res. **15**, 020115 (2019).