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Supporting scientists from underrepresented minority backgrounds

Mapping developmental networks

Underrepresented
minority

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Abstract

Purpose – The purpose of this study is to explore the developmental networks of graduate students of color participating in PROMISE, Maryland's Alliance for Graduate Education and the Professoriate program, a National Science Foundation (NSF)-funded graduate retention and support program. The authors specifically examine how underrepresented minority students gain access to needed supports through building individual mentoring relationships and broader networks of support.

Design/methodology/approach – The authors rely on a case study approach to explore developmental networks and support accessed by students participating in the PROMISE program. A total of 16 students of color in STEM fields from three institutions in the University of Maryland System have participated.

Findings – Study findings reveal that scientists from underrepresented backgrounds construct and draw from diverse developmental networks that include individuals from within and outside of the academic community. Key relationships include advisors; faculty with whom they share identities, peers in and outside of their programs; and administrators. Developers play distinct roles within the networks including shaping students' emerging professional identities as scientists and providing psychosocial support. Student agency and initiative as well as faculty engagement and programs like PROMISE further enhanced student access to mentorship.



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Research limitations/implications – This study offers unique insights into the nature, cultivation and resources gained from the relationships that make up the developmental networks of science graduate students from underrepresented backgrounds.

Originality/value – Traditional notions of mentoring and support, particularly in graduate education, highlight the role and importance of the student's advisor in their growth and development. This study is unique in its focus on the multiple relationships students of color in science form. This study offers specific insight into the nature, construction and resources gained from developmental networks formed by a group of underrepresented minority students in STEM graduate education.

Keywords Mentoring, Development, Support, STEM, Underrepresented minority students

Paper type Research paper

According to the 2017 National Science Foundation Report on Women, Minorities, and Persons with Disabilities in Science and Engineering, there have been recent increases in the representation of individuals from underrepresented minority groups (individuals who identify as black, Latina/o/x and native American) in STEM. The percentage of doctoral degrees awarded to underrepresented minority scientists has grown beyond its plateau of approximately 6.8 per cent in the early 2000s to 7.9 per cent in 2014. Despite this growth, disparities remain. Black, Latino and native American graduate students are less likely to complete their degrees than their white and Asian colleagues (Sowell *et al.*, 2015). Furthermore, underrepresented minority scientists seem less likely to enter the science workforce post-graduation (Lewis *et al.*, 2009), and early career scientists are largely white and male. Black women are 2.7 per cent of early career doctorate holders, 0.8 per cent are black men. 3.6 per cent are Hispanic women and 2.0 per cent are Hispanic men (NSF, 2017).

Mentoring relationships can potentially mitigate some of these disparities and promote student persistence, degree completion and retention in the science workforce by providing graduate students from underrepresented backgrounds with access to support, guidance and role modeling (Aspray and Bernat, 2000; Dixon-Reeves, 2003; Ong *et al.*, 2011; Thomas *et al.*, 2007). The access to information, resources and social connections mentoring relationships provide are related to graduate student persistence and successful entry into the research workforce post-graduation (Austin, 2002; Dixon-Reeves, 2003; Johnson, 2016). Mentorship can also provide students from underrepresented backgrounds with additional support and confidence (Antony and Taylor, 2004; Malone and Barabino, 2009; Ong *et al.*, 2011). This is particularly important given that research suggests underrepresented minority students are often subject to stereotypes and low expectations about their academic abilities (Antony and Taylor, 2004; Johnson-Bailey *et al.*, 2009), as well as isolation as one of few or the only person of color in their programs (Gasman *et al.*, 2008; Ong *et al.*, 2011).

As institutional leaders and national organizations institute mentoring initiatives, it is important to consider how to structure relationships that provide students with adequate support. Researchers have increasingly suggested that meeting graduate students' varied needs necessitates the development and cultivation of multiple kinds of relationships, emphasizing the importance of developmental networks, or "set[s] of people a protégé names as taking an active interest in and action to advance the protégé's career by providing developmental assistance" (Higgins and Kram, 2001, p. 268). In fact, several scholars and practitioners have argued that multiple mentors are no longer a luxury, but a necessity due to the changing nature of the workforce and the need for continuous knowledge acquisition (de Janasz *et al.*, 2003; Golde and Dore 2001; McAlpine, 2012; Rockquemore, 2016).

Despite the importance of access to mentoring for students from underrepresented backgrounds and an increasing emphasis on how multiple relationships can facilitate graduate student success (e.g. persistence, degree completion and a successful transition to the workforce), little research has focused on whether and how science graduate students from underrepresented groups gain access to the mentoring they need and develop networks of support. The purpose of this study is to explore how students build individual mentoring relationships and broader developmental networks. This study leverages an anti-deficit approach (Harper, 2010) and focuses on understanding that supports student success in science by examining the narratives of underrepresented minority scientists who have persisted and are successfully navigating graduate education. This work addresses the following questions:

- Q1. Who do underrepresented graduate students in STEM include in their developmental networks?
- Q2. How are developmental networks cultivated and maintained?
- Q3. How do individuals within these networks provide students with career and psychosocial support?

Background

Mentoring relationships are central in STEM graduate education and distinct from the role of an advisor or PI (Johnson, 2016). Advisors are largely expected to offer specific guidance and instruction that facilitates students' abilities to meet academic milestones, navigate institutional policy and assist in ensuring that degree requirements are completed. Mentoring relationships are often deeper, more enduring relationships that focus on personal and professional development through the provision of psychosocial and career support (Baker and Lattuca, 2010; Johnson, 2016). Career support is related to professional socialization and development, and includes exposing protégés to important networks, facilitating skill development and protecting them from unnecessary risks. Psychosocial support is connected to building protégé identity and self-worth, and includes counseling, friendship, acceptance and positive feedback (Kram, 1988).

There is some research that suggests that students from underrepresented backgrounds benefit from unique forms of psychosocial and career support within mentoring relationships. Some suggest that graduate students of color are more likely to succeed if their faculty adopt responsibilities above and beyond academic advising (Young and Brooks, 2008), integrating a proactive and empathetic stance and building personal relationships based on care and concern that encourage students to persist through academic challenges (Davidson and Foster-Johnson, 2001; Ostroff and Kozlowski, 1993; Patton, 2009). This may be particularly important, as many students of color are the first in their families to pursue graduate education, and may enter doctoral programs without the access to the unwritten rules necessary to thrive (Felder, 2010; Gopaul, 2011). In addition to psychosocial support, students from underrepresented backgrounds may benefit from unique forms of career support. For example, mentors who take the time to dissect and debunk myths associated with academia can make students' scholastic pursuits seem more attainable (Felder, 2010; Gasman *et al.*, 2004).

In addition to relationships with faculty, some research suggests that graduate students of color are more successful if they can cultivate peer-mentoring relationships (Young and Brooks, 2008). When faced with stressful situations, graduate students

describe the importance of assistance from peers and friends (Clark *et al.*, 2009; Janta *et al.*, 2014). Peer reinforcement can also mitigate feelings of isolation, and help to create a safe space and sense of community (Ellis, 2001; Gildersleeve *et al.*, 2011; Johnson-Bailey *et al.*, 2008). Peer relationships can be challenging for students from underrepresented backgrounds to cultivate when they have negative interactions with their white and Asian peers (McGee and Martin, 2011) or there are few students who share their identities with whom to build communal relationships (Kulis *et al.*, 1999; Williams *et al.*, 2016). To combat this isolation, research suggests that some students of color may begin to develop wider networks, cultivating close-knit relationships with those from universities nationwide (Felder, 2010).

While research has highlighted the importance of access to the career and psychosocial support mentoring provides, many underrepresented science graduate students struggle with forming strong relationships. González's (2006) research with Latina doctoral students, Felder's (2010) examination of African-American doctoral students and Robinson *et al.*'s (2016) work on black students' experiences show that students of color often have difficult or distant relationships with faculty and peers, who show little interest in them or their work. These struggles are often driven by racism and marginalization, as research suggests that faculty members and peers have lower expectations of underrepresented students and their abilities, are more likely to recognize their failures than successes and are less supportive or willing to offer guidance and support (Malone and Barabino, 2009; McCoy *et al.*, 2015; Noy and Ray, 2012; Robinson *et al.*, 2016; Thomas *et al.*, 2007; Williams *et al.*, 2016).

Conceptual framework

Higgins and Kram (2001) offered a conceptual framework, explaining how career (e.g. sponsorship, coaching) and psychosocial (e.g. role model and counseling) aid can be provided through networks of relationships, also known as developmental networks. Members of the networks are known as developers, who help protégés learn to define attributes, beliefs and values related to the professional role(s) they are expected to assume. This conceptual lens allows researchers to examine multiple, simultaneous one-on-one protégé/developer pairings (dyadic relationships), as well as the information transmitted throughout the larger network (Higgins and Kram, 2001). Protégé's engage and interact with various developers concurrently, and often for different reasons. For example, one developer may offer the protégé advice and assistance for developing pedagogical skills and managing teaching, whereas another developer can work with the protégé in managing work–life balance or navigating personal issues.

This perspective emphasizes two characteristics of protégés' networks: relationship strength and relationship diversity. Relationship strength speaks to the closeness between protégés and developers, capturing the frequency of interaction, level of reciprocity and positive emotions (Higgins and Kram, 2001). Strong ties often translate to more support, as individuals form stronger socio-emotional bonds and closer relationships (Dobrow *et al.*, 2012). Relationship diversity captures how well members of the network know each other and the different social systems developers occupy. Increased relationship diversity within a network provides protégés with new information and access to multiple forms of assistance (Higgins and Kram, 2001). Having a diverse network of relationships beyond the academic advisor can create opportunities for graduate students to access both career and psychosocial support in the forms of more comprehensive knowledge about their field and

future careers, technical skill development, reassurance and emotional encouragement (Baker Sweitzer, 2009; Baker and Pifer, 2011). Underrepresented minority

Methods

Research highlighting the importance of creating developmental networks is spreading to higher education, and may be particularly important for populations underrepresented in science, who often have limited access to needed support systems within the academy (Sorcinelli and Yun, 2007). We apply the Higgins and Kram's (2001) framework to guide this case study on the developmental networks of students of color in STEM. Case studies are ideal for gaining a deeper understanding of complex and current social phenomena, and is well suited to examine the process by which students develop and maintain developmental relationships (Merriam, 1998; Yin, 2014).

This case study examines how students participating in the National Science Foundation (NSF)-funded PROMISE program (<https://promiseagep.com/>), MD's Alliance for Graduate Education and the Professoriate (AGEP), form and benefit from developmental networks. The NSF created AGEP in 1999 to support the retention and degree completion of underrepresented minority graduate students in the STEM fields and better prepare them for faculty careers (American Association for the Advancement of Science, 2015). The PROMISE program, MD's AGEP (<https://promiseagep.com/>), serves graduate students within the University of Maryland System and focuses on creating a supportive community for underrepresented minority students to support their retention and professional development (Institute for Broadening Participation, 2014). They offer intensive dissertation writing workshops, student research symposia, networking conferences, professional development workshops and community-building celebrations. All students regardless of background or stage of degree program are welcome to participate in PROMISE events, and students choose their level of program engagement. The lead authors are affiliated with a social science research team that studies the PROMISE program; however, no author is involved with the administration of PROMISE events or program evaluation. This connection gave the authors' unique access to PROMISE administrators and a deeper understanding of the program.

Study participants and data collection

Data were collected from 16 participants who were enrolled as graduate students or recent graduates (within SIX months of data collection) from Big ($n = 8$), Suburban ($n = 5$) and City University ($n = 3$). Big University is classified as a Research University (very high research activity) and serves a large undergraduate and graduate student population, with approximately 10,000 graduate students. Suburban University is also a Research University, and has graduate programs in science, engineering and information technology, enrolling close to 2,800 graduate students. Finally, approximately 3,000 graduate and professional students attend City University, which is a Special Focus Institution, focused on business, law, public affairs and the sciences.

PROMISE program administrators served as key informants for this work, identifying students who had previously participated in PROMISE events for potential participation in the study. Identified students varied in their level of participation in PROMISE, with some attending events regularly, whereas others knew about the program, but rarely participated. Reaching out to administrators to identify participants was the most effective means of outreach given the team's non-evaluative role and lack of connection to the program's planning or administration.

The researchers invited each recommended student to participate in the study by email. A total of 16 STEM graduate students agreed to participate in one-on-one semi-structured interviews with the lead authors. Eight participants were male and eight were female. A total of 14 of the participants were black/African-American and two were Latino. Students were enrolled in graduate programs across multiple STEM disciplines. Seven participants were enrolled in engineering programs, one was in computer science and one was in environmental science. Four were in chemistry, two in biology and one in molecular medicine (Table I).

All interviews were recorded and later transcribed for analysis. Interviews were approximately 1-h long, and participants were asked to share information about the nature and quality of their experiences in graduate school, including their motivation to attend, interest and engagement in teaching and research and aspirations for post-graduation. We also asked students to describe the relationships that were most central and important to their development and the learning and to reflect on how they interact with faculty, exploring whether and how PROMISE activities related to their developmental interactions.

Data analysis

All data collected in this project were organized and analyzed through a systematic process. Once transcribed, all interviews were read multiple times. Each researcher wrote memos articulating key ideas and emerging themes appearing in each individual interview, as well as comprehensive memos that captured trends in the data overall. These memos were discussed and reviewed, serving as the foundation of a report of preliminary findings.

Interviews were then coded to further analyze the accuracy of researchers' early perceptions. Deductive codes were developed on the basis of the interview protocol, conceptual framework and key findings in the published research on the mentoring and relationship-related experiences of graduate students of color. Inductive codes were developed on the basis of a review of the memos and the identified emerging themes. The inductive and deductive codes were combined into one comprehensive codebook, each code marked by a definition and rules for usage. Once complete, each code was discussed, eliminating duplications, clarifying definitions and adding codes to capture missed

Pseudonym	Institution	Race/ethnicity	Sex	Field	Year in program
Angie	BigU	Black	Female	Chemistry	3
Brianna	BigU	Black	Female	Engineering	2
Erica	BigU	Black	Female	Environmental science	5
Felton	BigU	Black	Male	Engineering	6
Henry	BigU	Black	Male	Engineering	Recent graduate
Jackson	BigU	Black	Male	Engineering	4
Jordan	SuburbanU	Black	Female	Chemistry	3
MacKenzie	SuburbanU	Black	Female	Chemistry	Recent graduate
Marco	SuburbanU	Latino	Male	Computer science	4
Owen	SuburbanU	Black	Male	Engineering	2
Perry	BigU	Black	Male	Engineering	2
Ray	City	Latino	Male	Biology	Recent graduate
Richard	BigU	Black	Male	Chemistry	Recent graduate
Sandra	SuburbanU	Black	Female	Engineering	3
Sheila	City	Black	Female	Biology	3
Tanya	City	Black	Female	Molecular medicine	1

Table I.
Participants

phenomena. The codes were then applied to the data using Dedoose analytic software. After coding was complete, data were sorted by applied codes and clustered into themes to determine the validity of early impressions of the emerging themes and findings.

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Finally, each participant's developmental network was tracked and mapped. Each interview was read carefully, and authors recorded the relationships participants described in detail or indicated were important while in graduate school. Relationships were tracked on a spreadsheet (Table II), indicating all members of participants' networks. The team also noted the nature of the network and the individuals in it, with particular attention to relationship strength. So as not to prejudice or overly guide their responses, participants were not asked to characterize their relationships as either strong or weak. Rather, the research team coded and categorized relationships based on our analysis of participants' descriptions during their interviews.

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Trustworthiness, scope and limitations

The authors relied on several techniques to ensure the trustworthiness of the findings presented. First, interview protocols were developed on the basis of current literature and theory on mentoring and graduate education. We also pilot tested the protocol to ensure clarity and understandability, making revisions to questions that were perceived as redundant or unclear. Second, the two lead authors conducted the first three interviews jointly, debriefing immediately afterward to discuss the effectiveness of the protocol and establish consistency in interviewing style, mitigating biases and preferences related to ideas of mentoring and the doctoral student experience. The researchers debriefed throughout data collection, and met to discuss emerging themes as data were analyzed. Additional debriefing sessions were conducted upon completion of interviews to discuss emerging themes, which were corroborated with evidence and challenged with any disconfirming data.

While several steps were taken to ensure the trustworthiness of the findings, there are also limitations that must be acknowledged. The timing and resources of this project did not allow for follow-up with participants for member checks. This is a limitation as it potentially affects trustworthiness. There are also limitations associated with our sample. Participants were largely black, despite efforts to recruit Latina/o/x and native American students. Also, students were identified through their engagement in programmatic initiatives to support students of color in STEM graduate programs. Their participation in these activities may have shaped their networks and reliance on various dimensions (e.g. PROMISE programming), in ways distinct from those who do not have access to the PROMISE program or similar structures. Finally, while we understand and appreciate the importance of understanding how multiple marginalized identities create unique experiences of oppression for individuals from minoritized groups, this work does not include an intersectional analysis that explores differences based on the convergence of race, gender, class, sexuality or other relevant social identities.

Findings

Cultivating strong relationships with advisors

Every participant described their academic advisor or PI as part of their developmental network, and noted the importance and centrality of that relationship; however, these relationships varied in quality and strength. Stronger ties are relationships with more reciprocity, frequent communication and shared positive emotions (Higgins and Kram,

Table II.
Mapping of
participants'
developmental
networks in graduate
school

Pseudonym	PI/Advisor	Other faculty	Staff	Peers (in same lab or program)	Peers (in graduate school)	Program directors and administrators	Working professionals in the field	Undergraduate or previous faculty	Family and friends outside of school
Angie	x	x	x	x	x	x		x	x
Brianna	x	x	x	x	x	x	x	x	
Erica	x	x		x		x			x
Felton	x	x		x	x			x	x
Henry	x	x							x
Jackson	x	x		x	x		x		
Jordan	x	x	x	x	x	x			
Mackenzie	x	x	x	x	x	x			x
Marco	x					x	x		x
Owen	x	x		x		x		x	
Perry	x	x				x		x	
Ray	x	x	x			x			
Richard	x	x					x		x
Sandra	x	x				x			
Shiela	x							x	x
Tanya	x					x		x	x

2001). Students who formed strong ties with their advisors perceived these relationships as more helpful, facilitating their access to career support and important opportunities to develop their skills, abilities and knowledge about scientific inquiry. Participants generally stressed the importance and value of having an advisor who supported their academic endeavors and provided direct guidance and assistance as they learned how to engage in science, particularly in the laboratory. Sheila explained that faculty should meet multiple objectives to produce successful scholars, including teaching students “how to be independent researchers,” providing “guidance about appropriate conferences” and facilitating discussions and avenues that would help students seek collaborations. Ray explained that his scholarly collaboration with his advisor helped him learn “how to put all my stuff done on paper and communicate it effectively, within word limits.”

Strong relationships went beyond advisors offering opportunities to engage in research and advice; students valued and formed strong bonds with faculty members who offered psychosocial support. Richard noted that his advisor was always present and available in the laboratory and was widely known as not only a good scholar but also a “nice guy” who intentionally formed strong relationships with students and colleagues. Ray stated that he really valued having an advisor who “displayed an interest” in seeing him succeed, and that their strong relationship provided insight into grant writing and the publication process, demonstrating how “it [science] works in the real world. Especially communicating your science and writing.” Angie explained the relationship between the support she received from her advisor and her confidence as a scientist. After a negative relationship with her previous advisor, Angie “felt very down and depressed.” Joining a new research group and building a strong bond with her new advisor:

[. . .] built my confidence. She is constantly encouraging me to apply for different things and she’s helping me now with looking for different jobs [. . .] she’s very understanding and it’s helped me out a lot.

Thus, in multiple cases, psychosocial support translated to students’ increased confidence in their skills and abilities.

Conversely, some students had weak or negative relationships with their advisors. Sandra juxtaposed her advisors’ busy schedules with their encouragement and faith in her abilities. She noted that she would not have been able to get as far without their socio-emotional backing; however, graduate students and other members of the department needed to step in to offer career support and advising, helping her meet financial, academic and social needs. Negative relationships, in particular, appeared to hinder participants’ academic progress. Henry had a particularly contentious relationship with his first advisor at Big University, describing him as discouraging and disinterested in his research. Henry described a relationship that lacked clear communication and expectations, sharing:

If he would have just told me that he no longer wanted to either work with me or continue the project, I would have left [. . .] But he just kept moving the goal post and creating objectives that were harder and harder to complete, so I would just work harder and harder to complete them.

After three years, Henry’s advisor cut his research project. This was a significant setback in terms of his confidence and timeline to complete his degree, and Henry had to find a new advisor and a laboratory in which to work. Marco had two advisors, and appreciated the moral support one provided as he transitioned between degree programs. However, he noted his frustration with their lack of direct guidance and involvement in his research, connecting

their lack of clarity and engagement to his confusion about his research and future in the field. He shared, "I don't understand what they want from me, what they expect from me and what I can expect from them [...] I'm confused [...] I never receive any straight answers."

Benefitting from relationships with multiple faculty

In addition to developing relationships with their advisors, most ($n = 14$) participants described the importance of forming relationships with other faculty. Being able to develop relationships with multiple faculty members allowed Erica to access resources she needed to make progress in her research and science learning, and she appreciated the open door policy to which most faculty in her department subscribed. Felton was able to build relationships with two faculty members, for whom he served as a teaching assistant, which provided him with important insights into teaching techniques. Not having other faculty in one's network could also be perceived as a disadvantage. For example, Marco knew that faculty relationships were important to cultivate, and noted that not having these relationships left him feeling a lack of fit in his program, sharing:

I feel like I can't really like talk to my professors, like there's no relationships that I've developed there, so I'm going to try to be more active in terms of trying to develop those relationships.

Some participants diversified their networks by intentionally forming relationships with faculty at their institution who were also members of underrepresented groups and shared their identities. Richard befriended a black professor who was the PI of a nearby laboratory, who offered insights into the nature of the academy and his own career path as a black man. MacKenzie valued the insights of a female faculty member that was on her dissertation committee as she prepared to apply for postdoctoral fellowships. In addition to career support, this professor reminded her to appear confident, acknowledging that "as women, we tend to play our roles down a little bit." MacKenzie noted that this was psychosocial support and advice that she needed to hear at that moment, and was distinct from the more content and career related suggestions she received from her advisor.

Finally, nine participants talked about the important role faculty members outside of the institution played in their developmental networks. Angie keeps in touch with her mentor, who advocated for her to pursue a doctoral degree. She also shows a special affinity for her mentor and is careful not to "let her down," even though she decided to leave her program with a master's degree rather than completing her PhD. Doctoral students like Brianna who had previously completed master's degree relied on faculty that supported them during that process, particularly for advice and access to networks at their new institutions.

Learning with and from peers

Peers were also instrumental to student success, and 15 of the 17 participants described peers' roles in their developmental networks. Six participants highlighted the importance of their relationships with peers both in and outside of their academic programs, three noted that their networks included peers only from their lab or department and five described networks that included peers only outside of their departments and programs.

Connections to peers in their laboratories and programs provided students with information and support distinct from what they received from faculty. Jackson shared

that his relationship with his advisor was more focused on signing paperwork and getting him through the program. He identified senior graduate students as his mentors, who:

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[. . .] helped you learn what you need to study, who you should talk to for this, how you should go about research, the type of questions you should ask. So kind of helping you do the research process. The adviser was more, like, checking your work and looking at the overall, bigger scheme.

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Interactions with peers provided Jackson with information that helped him navigate the graduate school environment from day to day, whereas his advisor was more concerned about his overall progress. Similarly, Erica and Angie both discussed the role of peers as vitally important to navigating day-to-day academic challenges and advisor relationships in the lab, respectively.

Relationships with peers outside of one's academic program could also provide important support. Richard explained that he and his best friend were completing PhDs at the same time. Sharing similar struggles created a level of understanding that was distinct from the help he could receive from his advisor or parents. Brianna had a deeper understanding of how to manage and address her concerns about her training experiences based on her conversations with students from other graduate programs and institutions. These conversations helped her "learn how to navigate, making sure [. . .] you do things in the proper way and understanding your options and kind of how to go about completing your degree," if and when she had to address concerns with a professor. Sandra had two advisors who she rarely saw and worked alone in her laboratory, and described the importance of forming relationships with other graduate students to aid her journey. She participated in campus events hosted by PROMISE and other programs focused on increasing access and inclusion in science, which allowed her to gain access to assistance and nurturing, build her networks and learn more about how other students "got past the difficult parts of their journeys to be where they're at now." Thus, peers were able to provide encouragement distinct from advisors, particularly in providing insights into the day-to-day work of graduate school, navigating departmental politics and processes and persisting through challenges.

Relationships with program administrators

In addition to peers and faculty, program directors and administrators also became part of several participants' developmental networks. Ten students described relationships with institutional leaders and program administrators that provided either social or academic support. Erica noted a relationship she developed with an administrator that helped her think in new ways about her pedagogy and teaching. Angie offered that there was an administrator who served as the executive director for her academic program with whom she visited once a week for academic and personal advice. Owen talked about forming a relationship with his institution's president, which pushed him to be intentional and specific about his goals as they engaged in conversations about his career.

Multiple participants described the strong relationships they were able to build with the director of the PROMISE program. The director appeared to pair career and psychosocial support, encouraging students to stay focused and helping them develop new connections. Marco and MacKenzie described the director of PROMISE as "supportive" and "very encouraging," wanting her students to be prepared with the best information so they could make informed decisions. Marco shared the following experience:

When things didn't work out in my first department, I thought I was going to have to drop out and then at one point, I looked at loans and I was freaking out. I didn't know what I was going to do. My old department wasn't being very cooperative and I spoke to [the PROMISE director and another faculty member] and between the two and [a senior administrator] and other people in the graduate school, even people I never met, they were just very supportive and they mobilized and they spoke. They made it so that I could stay in school and if I got good grades in my classes that I would be accepted in my current department.

Marco went on to share that he appreciated the ways the PROMISE director and other campus administrators not only provided him with access to resources but also believed in him and his potential, encouraging him not to leave graduate school.

Gaining access to support: network development and maintenance

Accessing and maintaining ties with faculty. While a few participants described developing relationships based on classroom interactions or serving as a teaching assistant, stronger connections were mostly developed during interactions around research. In many cases, faculty created opportunities for students to engage through open-door policies, lab meetings and individual sessions; however, some participants noted that accessing faculty and maintaining these relationships required student agency. For example, Perry recently decided to attend his co-advisor's weekly lab meeting in order to get access to more "nuts and bolts," and specific guidance on how to complete his project. Jordan explained that he and his advisor had a "really good relationship," developed through their bi-weekly group meetings and individual weekly check-ins with members of the lab. Erica's advisor used an open door policy as one of the multiple strategies to make herself available to students:

[...] We have an open door policy. We have a lab group for our research lab [...] We meet once a week, and if anyone has problems, we'll kick them back and forth, but if you have a problem that's going to require extra attention then you can schedule something that's outside of that meeting. For her graduate students or her undergrads who are actually trying to publish something, then you can come to writing hours [...] if you had a concern that you were caught up on a particular part of writing then you could go up to the corner and get some assistance with her.

Thus, Erica's advisor offered multiple opportunities and ways to meet with her individually or in small groups to gain important career support. Choosing to engage in these meetings and ask questions facilitated growth and learning, as students were able to get answers to their questions and develop insights into what it means to complete academic work.

Regular contact appeared to foster relationship strength over time, leading to deeper levels of connection and career support. Felton shared how conversations with his advisor typically started with him asking how to solve a problem in his research, but then turned to where he saw himself in a few years. Together, they discussed strategies Felton could use to reach these goals. Similarly, Angie saw her advisor almost daily. While some of their conversations were about research, the frequency of their meetings allowed them to talk about her broader career goals and interests. Owen added that his professional relationship and interactions with his advisor became more personal and focused on his long-term career development over time:

[...] it started off a professional relationship but like throughout the research process and meeting with him one on one, it actually transferred over to like more of personal relationship, too. [He] told me like just like life lessons [...] but within the context of [computing] and the PhD.

In sum, access to long-range career advice and guidance was often not immediate, but evolved over time as students engaged in community practices and through interactions with faculty members. Underrepresented minority

Programs fostering relationship diversity. Participants also described programmatic initiatives that helped them access developers and maintain their networks. Owen, Marco and Sandra described how PROMISE and other campus programs facilitated connections with peers and faculty members that were also underrepresented in science. For example, Owen and Marco credited their involvement with campus programs and organizations focused on uplifting students of color in science as creating spaces that helped them to establish and sustain beneficial social relationships with peers, faculty, university administrators and potential mentors. Although programs in which students were engaged varied in mission and scope, they offered similar forms of academic and social programming, creating community across campus, and sometimes across institutions.

PROMISE was frequently included as a program that did this kind of work, providing students with access to information and individuals that could improve their development as scientists. Sandra shared “PROMISE constantly has a lot of networking events [...] just bringing people together and being able to talk to them,” creating opportunities for social support and engagement. Erica noted that it was sometimes difficult to be the only black student in her program, and that activities offered through PROMISE provided a way to connect with students across campus and gain access to important information and mentorship. Angie also noted that there were very few black students in her department and that she initially found it difficult to network with students on her campus. PROMISE created an opportunity to meet and connect with someone who is now her “best friend on campus,” who was in a different academic program.

Although most participants spoke of the student developers to which they gained access, there was some recognition of how the spaces PROMISE created through their programming and initiatives created opportunities to access and develop ties with faculty. For example, Marco had some negative interactions with faculty and, at times, was unsure if he would be able to complete his degree. However, PROMISE and other campus programs allowed him to develop faculty relationships outside of his department that validated him and motivated him to keep going. Brianna mentioned that attending PROMISE workshops and conferences exposed her to good networking opportunities with faculty and entrepreneurs in her field.

Discussion

Our findings suggest students construct and rely on diverse developmental networks, including their advisors, underrepresented minority faculty, peers in and outside of their programs, administrators, parents and other family members as they navigate graduate school and strive to become scientists. Developers play distinct roles within the network, collectively providing the career and psychosocial assistance students needed. While gaining access to developers and maintaining relationships required both faculty and student agency and initiative, programs like PROMISE, which created a sense of community and provided information to underrepresented scientists, also facilitated access to developers.

Going beyond a focus on individual relationships with advisors or peers, this work provides insight into the unique forms of help various developers within a network can (and cannot) offer. PhD supervisors and advisors focused primarily on career support, offering

scientific knowledge and access to opportunities to cultivate skill development and science competency. While faculty outside of the academic program diversified students' developmental networks and provided career support through access to professional contacts and research training and resources, advisors were described as being most central to the career development process.

Students' descriptions of their relationships with faculty advisors suggest that consistent with [Higgins and Kram's \(2001\)](#) framework, access to career support was somewhat dependent on relationship strength. Students who engaged more and developed stronger relationships with their advisors gained access to more complex career support in the form of specific guidance on research, as well as advice and feedback on their longer-term professional development, goals and interests. While these findings are somewhat similar to research that suggests underrepresented students desire deeper personal connections and more psychosocial support than traditional advising relationships require ([Davidson and Foster-Johnson, 2001](#); [Patton, 2009](#); [Young and Brooks, 2008](#)), this work is unique in its clarification of a connection between psychosocial support and academic and career development. Thus, in addition to ensuring that science graduate students from underrepresented backgrounds have mentors, it is important to attend to relationship quality, ensuring faculty demonstrate their investment in students' success, maintain a level of accessibility and make continued contact to promote both students' psychosocial and career outcomes. It may be particularly important to train and incentivize faculty to engage in these behaviors, given that underrepresented students in science often perceive faculty as disengaged and disinterested in their work, or inconsistent in their investment ([Felder, 2010](#)).

Previous work highlights the importance of peer relationships in graduate education ([Clark et al., 2009](#); [Janta et al., 2014](#)), and several studies suggest graduate students of color often rely on peers for comfort and information when faced with stressful situations or negative relationships with faculty ([Bonilla et al., 1994](#); [Ellis, 2001](#); [Gildersleeve et al., 2011](#)). Regardless of relationship quality with faculty advisors, peers offered career support that was distinct from faculty developers. Peer developers helped participants navigate day-to-day expectations and responsibilities in the laboratory, as well as departmental politics. Peers also provided social and emotional assistance based on their shared experiences and unique understanding of what it means to be a graduate student. Many of these interactions took place organically and informally. Yet, implementing peer mentoring programs may create more uniform access to the information and support peers can provide given that graduate students of color often have challenges forming connections because of peers' stereotypes about the abilities of scientists from underrepresented backgrounds ([Robinson et al., 2016](#); [Williams et al., 2016](#)). In other words, a lack of guidance and structure may leave students of color on the outside of valuable peer connections.

Our findings also confirm previous work that suggests students from underrepresented backgrounds often seek those who share their identities and feel a unique sense of community and closeness with faculty and students of color ([Baker et al., 2014](#); [Patton, 2009](#)). Our study adds nuance to this scholarly conversation, highlighting the specific ways faculty developers from underrepresented backgrounds provide underrepresented minority graduate students with a hybrid of career and psychosocial support their advisors or faculty in their academic programs did not. Faculty who shared their identities not only offered career insights but also spoke to participants' identity-based needs and concerns, sharing advice on how to navigate sometimes marginalizing spaces. Relationships with other graduate students from underrepresented backgrounds created opportunities to share stories about navigating barriers and find a deeper sense of belonging through community

connection. This is support graduate students from underrepresented groups often lack in their home departments and programs (Gay, 2004; Gildersleeve *et al.*, 2011; Griffin *et al.*, 2016). This reminds that the role played by a faculty member or peer community that shares a student's most salient identities is distinct, yet complementary, to the assistance offered by advisors and lab mates (who may or may not share that identity). Having strong relationships with one's advisor or peers does not replace the needs filled or support received by developers who share marginalized identities with their protégés, and vice versa. Institutional leaders and faculty must continue to create opportunities to cultivate opportunities to form all of these distinct connections.

While they have received little attention in graduate education research and the developmental networks literature, relationships with higher education administrators and institutional leaders can also offer underrepresented graduate students important resources and help, particularly as they experience marginalization and isolation in their academic departments. For example, Griffin *et al.* (2016) found that administrators working on initiatives focused on access and inclusion in graduate education often coupled opportunities to learn about strategies to navigate graduate education with community development and social support. Thus, encouraging students to see these administrators as not only individuals coordinating programs but also valuable members of their developmental networks may provide another source of support for underrepresented students who find feel that their home departments and programs are hostile or unwelcoming.

This work also offers insights into how diverse developmental networks are formed and maintained, highlighting the importance of both formal and informal opportunities for engagement, as well as a degree of student agency. Participants in good mentoring relationships are often described as having excellent chemistry; however, these kinds of observations do not lend themselves to helping other mentors learn things they can do to improve their relationships and the quality of their connections (O'Meara *et al.*, 2013). Findings from this work suggest developmental relationships were formed and deepened through professors initiating contact and creating opportunities to engage. Faculty accessibility was key, and students saw open-door policies, one-on-one meetings and lab meetings as opportunities to gain feedback and guidance. It is important to note that consistent with Higgins and Kram's (2001) framework, strong ties took time to develop, as students and advisors built emotional connections, trust and reciprocity in their relationships. Thus, we recommend that graduate departments and programs incentivize faculty to be intentional in creating multiple opportunities to engage with students, providing faculty with resources and guidance as they develop mentoring strategies.

At the same time, it is important to acknowledge that strong ties were also developed through student agency and engagement; participants played an active role in cultivating their networks generally, and relationships with their advisors specifically. This supports research by McAlpine (2012), which views doctoral experiences through a lens of identity-trajectory that highlights students' agency, resourcefulness and independence. McAlpine also pointed out that structure plays an integral part in students' doctoral experiences and influences their ability to show a sense of agency. It is important to note that we are neither suggesting that students of color are solely responsible for their relationships with faculty, nor that they should feel burdened by the need to initiate the development of each relationship. However, participants in this study had to be ready to seize opportunities presented to them, be willing to engage faculty when space was created, reflect on what they needed and ask for support and resources. Furthermore, while programmatic interventions focused on the development of underrepresented students in science were described as

useful, students had to choose to take advantage of and actively participate in these programs. Institutional leaders and faculty must take intentional steps to remind students of their role in developing their own developmental networks, being mindful that some may be reluctant to appear so strategic (McAlpine, 2012). Orientations and trainings that offer graduate students guidance and encouragement about how to build relationships with faculty early in their academic programs, gain access to resources and connect with responsive communities could be helpful strategies to foster student agency.

Expanding access to quality mentorship for scientists of color has been identified as a national priority and an important strategy for increasing student success (National Academy of Sciences, National Academy of Engineering and Institute of Medicine, 2010). As scholars, institutional leaders, policymakers and faculty continue to consider and implement strategies to promote the retention, career development and success of graduate students of color in science, we encourage them to continue to implement mentoring policies and programs that integrate the lessons learned from this research. Faculty and graduate program directors can work more intentionally with graduate students of color to assess their networks and how they are meeting student academic and social needs. Such assessment could reveal the dimension of networks most challenging to cultivate and suggest new interventions to build stronger networks in these areas, supporting the persistence and career advancement of underrepresented students.

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Underrepresented
minority

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