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Bridge Building: How Cross-Sector Collaborations Can Be the Silver Bullet to Address the Cybersecurity Workforce Shortage

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ABSTRACT: The global cybersecurity workforce shortage presents a critical challenge for national security and economic stability, and under-representation among students of color further exacerbates the shortage. Many collaborative programs have been developed to address these issues, yet inequities persist, and little research focuses on how these programs affect the accumulation of social capital. This article examines how collaboration across industry, academia, government, and community organizations can build pathways to engage and retain underrepresented students in cybersecurity. Drawing on social capital theory, the study highlights how networks, resources, and equity-centered approaches foster opportunities for participation. A review of two initiatives illustrates the value of industry-driven internships, government-supported scholarship programs, university partnerships, and community outreach in expanding exposure and support systems. Findings suggest that multi-sector collaboration not only enhances student awareness and skills but also addresses systemic barriers by building trust, providing mentorship, and integrating culturally responsive practices. The article concludes by outlining policy and practice implications, emphasizing the need for sustained investment in collaborative frameworks to diversify the cybersecurity workforce.

KEYWORDS: cybersecurity workforce, diversity, students of color, social capital theory, critical race theory, industry-academia-government collaboration, community outreach, workforce development, equity in STEM

Introduction

The desire to address the underrepresentation of minorities in STEM education and employment has led to the development of many collaborative programs designed to support greater engagement and representation of women and people of color in science, technology, engineering, and mathematics (Braswell et al., 2024; Brumfield & White, 2024). Collaboration among industry, academia, government, and community organizations offers a promising approach to cultivating this social capital for marginalized students (Barber et al., 2021; Rocha et al., 2022). However, the shortage of skilled professionals in the cybersecurity

workforce persists, as do racial and gender inequalities (Cheryan et al., 2025; Masamoto et al., 2024).

The cybersecurity workforce shortage represents a pressing concern for national security, economic growth, and technological innovation (Osman et al., 2023). Hundreds of thousands of cybersecurity positions remain unfilled in the United States, while global demand and cyber threats continue to escalate (Nyame et al., 2024). Beyond the dire consequences to national security, inequities in representation among students of color remain a critical challenge, limiting both the diversity of perspectives and the inclusivity of opportunities within the field (Sedlacek et al., 2025). Addressing the dual concerns of an expanding workforce gap and the underrepresentation of marginalized groups requires more than isolated interventions; it necessitates sustained, cross-sector collaboration (Chibunna et al., 2020; Rocha et al., 2022).

Industry partners contribute internships, apprenticeships, and mentorship opportunities that expand professional networks (Rocha et al., 2022). Academic institutions provide curriculum design, skill-building programs, and direct access to higher education pathways (Brumfield & White, 2024; DaSilva et al., 2023). Government agencies fund scholarships, create policy frameworks, and incentivize partnerships to broaden participation (Center for Strategic and International Studies, 2021; Leithauser, 2023). Community organizations play a vital role in outreach, cultural responsiveness, and sustained encouragement (Bailey et al., 2022; Braswell et al., 2024). Together, these stakeholders can generate the networks, resources, and trust that social capital theory identifies as essential for fostering access and long-term engagement. However, little research has examined the efficacy of collaborative programs or their influence on the accumulation of social capital.

Efforts to diversify the cybersecurity pipeline must account for the systemic barriers that students of color encounter in education and workforce transitions (Sedlacek et al., 2025). These barriers include limited access to high-quality STEM instruction, fewer opportunities for mentorship, and fewer professional networks than their peers (Lamb, 2025). Social capital theory provides a useful framework for analyzing how collaborative programs address these challenges, as the theory emphasizes the role of social networks, institutional relationships, and resource-sharing in shaping opportunities and outcomes (Saw, 2020; Schmid & Robison, 1995; Wao et al., 2023).

Problem Statement

Racial disparities in STEM achievement between minority and White students emerge long before university (Morgan et al., 2023) and persist through graduation to employment, exacerbating shortages in the cybersecurity workforce (Fry et al., 2021). Research suggests that racial disparities in educational achievement can be reduced by increasing access to resources and support

(Morgan et al., 2016; Rocha et al., 2022), and collaborative programs have emerged to promote STEM diversity at the university level (Palid et al., 2023). While collaborative programs designed to support minority participation in STEM often use social capital techniques like bridging, bonding, and linking (Park et al., 2021; Saw, 2020), these programs are rarely examined from multiple stakeholder perspectives to identify how distinct concepts associated with social capital theory influence student experiences or their perceptions and attitudes toward STEM degrees and careers. This study addressed multiple gaps in the literature by examining two collaborative programs aimed at promoting minority engagement in STEM at the high-school level. Using social capital theory to explore these programs from a multi-stakeholder perspective provided critical insights into how support networks increase minority student access and foster feelings of belonging and trust.

Purpose Statement

The purpose of this research is to use social capital theory to examine how additional support, provided through collaborative partnerships, influences the underrepresentation of minority students in STEM. Specifically, the study sought to explore how cross-sector collaboration among (a) mentors and industry professionals, (b) educators and program coordinators, and (c) community leaders participating in STEM education, mentoring, and career development programming can expand opportunities for students of color and support participation in cybersecurity careers. Specifically, the research investigates 3 research questions:

RQ1: How do collaborative initiatives generate social capital that benefits underrepresented students?

RQ2: What models of partnership have proven effective in reducing barriers to participation?

RQ3: How might these collaborations inform policy and practice to strengthen diversity in the cybersecurity workforce?

By situating the analysis within social capital theory, this study underscores the potential of multi-sector collaboration to build pathways that are not only accessible but also sustainable in addressing both the workforce shortage and the imperative of equity.

Theoretical Framework

Social capital theory provides a valuable lens for understanding how students of color can access, navigate, and thrive in pathways leading to cybersecurity careers. First introduced by Pierre Bourdieu (1986) and further developed by Coleman (1988) and Putnam (2000), the theory posits that individuals benefit not only from personal knowledge and skills but also from the networks, relationships, and

resources embedded within their social environments. In this sense, capital extends beyond financial and human capital to include the trust, reciprocity, and connections that enable individuals to achieve outcomes otherwise unattainable in isolation. Social capital theory centers on the idea that resources, opportunities, and support are embedded in social relationships and networks (Putnam, 2000). Unlike human capital, which emphasizes individual knowledge and skills, social capital emphasizes the relational and collective dimensions of success. Social capital is typically categorized into three forms: bonding, bridging, and linking (Mohiuddin et al., 2025). Bonding social capital refers to strong, inward-looking ties within homogeneous groups, such as family, peers, or identity-based communities (Tuominen et al., 2023). Bonding provides emotional support, trust, and affirmation among individuals who share similarities. Bridging social capital connects individuals across diverse groups, offering exposure to new opportunities, perspectives, and resources. Bridging helps individuals advance their goals by broadening access beyond their immediate circles (Tuominen et al., 2023). Linking social capital involves connections to institutions, structures of authority, or formal systems that provide legitimacy, power, or access to resources beyond community control (Glass, 2022).

In the context of cybersecurity, these forms of social capital explain how students of color gain access to technical opportunities (bridging), sustain motivation through peer and mentor support (bonding), and secure legitimacy and pathways into institutions such as universities, industry, and government (linking). Social capital theory thus provides a comprehensive framework for analyzing how cross-sector collaborations can address inequities in the cybersecurity pipeline. Bourdieu (1986) emphasized that social capital reflects the aggregate of resources linked to durable networks of relationships, often unequally distributed across social groups. Coleman (1988) expanded on this by highlighting the role of social capital in educational contexts, where networks of trust and collaboration can facilitate learning and opportunity. Putnam (2000) later underscored its civic dimensions, framing social capital as a collective resource that strengthens communities and institutions. Taken together, these perspectives suggest that access to robust networks is both an individual and structural advantage, one that is often limited for underrepresented populations due to systemic inequities.

Applied to the cybersecurity pipeline, social capital theory suggests that students of color may face barriers not because of a lack of ability or interest, but because of restricted access to networks of opportunity, such as mentors in industry, professional role models, or institutional advocates. These networks provide more than information; they supply encouragement, cultural validation, career guidance, and exposure to professional norms. Without such resources, students may find it difficult to envision themselves in the field, much less persist in it. Cross-sector collaboration among industry, academia, government, and community organizations can cultivate the social capital needed for student

success. Industry partners can introduce professional mentorship and experiential learning opportunities that connect students with industry insiders. Academic institutions can function as bridges, embedding partnerships into curricula and offering sustained guidance. Government initiatives can fund and institutionalize programs that expand access to underrepresented communities (Leithauser, 2023; Palid et al., 2023). Community organizations, often rooted in trust and cultural relevance, can help overcome barriers of exclusion by validating students' identities and providing localized support networks (Montoya et al., 2021).

By drawing on social capital theory, this study frames multi-sector collaboration as a mechanism for building networks of opportunity that extend beyond traditional educational structures. Such networks are essential for ensuring that students of color are not only introduced to cybersecurity as a field of study but also supported in ways that make long-term engagement and career success more attainable. In this way, the theoretical framework underscores both the systemic nature of inequities and the transformative potential of collaborative interventions that strategically build social capital.

Originality, Rationale, and Significance

While the literature on diversity and equity in STEM spans a wide range of research, few studies focus on the overarching question of how social capital is created and used in collaborative programs. Studies on mentorship, such as those by Braswell et al. (2024) and Vierra et al. (2024), examine critical mentorship dynamics (bonding capital) but do not always fully address issues of access (bridging capital) or feelings of belonging (linking capital). Similarly, studies on camp experiences (see Bailey et al., 2022; Hayder & De La Cruz, 2025) focus on bonding and belonging opportunities but fail to adequately address formal network-building and access issues. This study addresses a gap in the literature by exploring how social capital is generated and used to reduce barriers to minority students' participation in STEM.

This study is significant because it adds to the body of knowledge on equity in STEM fields by exploring how collaborative programs help students build and use social capital (e.g., bridging, bonding, and linking). Students who possess strong social capital are more likely to access career pathways that may otherwise remain closed to them, and research shows that mentorship, exposure to professional communities, and supportive institutional ties strengthen social capital (Bottia et al., 2021). This study aimed to extend the trend of previous research by evaluating program efficacy and contextualizing the findings using the lens of social capital theory. Additionally, this study provides insights into program efficacy from multi-sector and multi-stakeholder perspectives, currently missing from the literature.

Methodology

This study employed a qualitative research design to examine how cross-sector collaboration among industry, academia, government, and community organizations fosters social capital for students of color in the cybersecurity field. Qualitative inquiry allows researchers to explore the meanings individuals attribute to their experiences and the social processes shaping them (Creswell & Poth, 2018; Merriam & Tisdell, 2016). Social capital theory guided the study by focusing on the networks, trust, and resources generated through collaborative initiatives.

Site and Participant Selection

Two collaborative initiatives were purposefully selected as case sites to examine diverse models of partnership. The first was an industry-academia internship program designed to provide underrepresented high school and college students with direct exposure to cybersecurity careers. The second was a government-community scholarship initiative that paired financial support with mentorship and outreach activities in underserved neighborhoods. Participants were recruited from across these programs using purposive sampling (Ahmad & Wilkins, 2024). The sample included:

- Students of color (n = 24) who engaged in the programs, representing both high school juniors/seniors and early college students
- Mentors and industry professionals (n = 18) who provided guidance and training
- Educators and program coordinators (n = 12) who oversaw curriculum and student support
- Community leaders (n = 8) who facilitated outreach and cultural engagement

This combination of perspectives enabled a holistic understanding of how collaboration generates social capital at various levels of the pipeline.

Data Collection

The data collection process incorporated three qualitative methods: semi-structured interviews, focus groups, and document analysis. Semi-structured interviews were conducted with students, mentors, and program leaders (Chand, 2025). Students also participated in focus groups to identify shared challenges and opportunities. All interviews and focus groups were audio-recorded, transcribed, and anonymized. Finally, program materials, partnership agreements, and recruitment artifacts were gathered to support document analysis (Chand, 2025).

Data Analysis

Thematic analysis followed the six-phase process outlined by Braun and Clarke (2006). Codes were developed both deductively from social capital theory

(bonding, bridging, linking) and inductively from the data. Themes were refined into three categories: (a) Access, (b) Networks of Support, and (c) Belonging & Trust. Member-checking with participants and peer review of coding enhanced credibility (McKim, 2023).

Trustworthiness and Ethics

Credibility was ensured through methodological triangulation and participant triangulation. Thick description supported transferability, and an audit trail strengthened dependability and confirmability. Institutional Review Board approval was obtained, and informed consent (and parental consent for minors) was secured.

Findings

Three themes emerged from the analysis, each of which aligns with a form of social capital.

Theme 1: Access (Bridging Capital)

Collaborative programs expanded students' opportunities, internships, and exposure to professionals, allowing them to connect to networks beyond their immediate communities (Saw, 2020). These bridging relationships enabled students to envision cybersecurity as an attainable career. Students frequently described how industry partnerships provided exposure to professional environments and career possibilities they had not previously considered (Jabbar et al, 2021). Additionally, other programs showcase how parent outreach and school–community partnerships build bridging social capital that later funnels students into enrichment opportunities; applicable when designing outreach to families of Black and Latinx youth for cybersecurity camps and programs (Murray et al, 2020).

Theme 2: Networks of Support (Bonding Capital)

Students emphasized the importance of peer and mentor networks that provided encouragement and understanding (Estrada et al, 2016). This bonding social capital reinforced resilience and belonging, creating a safety net for persistence. Mentorship relationships, particularly those involving professionals who shared similar backgrounds, were identified as crucial for maintaining motivation and navigating challenges. Strong within-group ties (peer cohorts, near-peer mentors, student organizations) are consistently associated with increased persistence and well-being for underrepresented students in STEM (Mishra, 2020).

Theme 3: Belonging & Trust (Linking Capital)

Representation, cultural responsiveness, and institutional trust were essential to sustaining engagement. Community partners played a critical role in linking students with institutions, validating their experiences, and fostering legitimacy in

the cybersecurity field (Gentry et al, 2025). Students reported that seeing professionals who shared their cultural backgrounds increased their confidence in pursuing cybersecurity careers. An institutional academy model that formalizes university–industry linkages (scholarships, apprenticeships, sponsored labs) and shows how structured linking relationships build trust and create sustained career pathways for underrepresented students (Obstfeld, 2023).

Table 1. Participant Characteristics

Participant Group	*N*	Role in Collaboration	Example Contribution
Students of Color	24	High school juniors, seniors, and early college	Shared lived experiences in programs
Mentors/Industry Professionals	18	Cybersecurity practitioners	Provided mentorship, training, and exposure
Educators/Coordinators	12	Teachers, faculty, program managers	Oversaw curriculum, student support
Community Leaders	8	Nonprofit and outreach representatives	Built trust, facilitated engagement

Table 2. Themes, Definitions, and Examples

Theme	Type of Social Capital	Definition	Illustrative Example (Student Quote)
Access	Bridging Capital	Expanding connections beyond immediate community	"This internship helped me meet professionals I'd never know otherwise."
Networks of Support	Bonding Capital	Strong ties offering emotional and academic support	"My mentor understood my background. It made me feel I could belong here."
Belonging & Trust	Linking Capital	Trust and legitimacy connecting students to institutions	"Seeing leaders who look like me made me believe I could succeed in this field."

Discussion

This study demonstrates that social capital (e.g., bridging, bonding, and linking) is central to understanding how cross-sector collaborations foster student engagement in cybersecurity. Access aligns with bridging capital by expanding professional networks; support networks reflect bonding capital, providing encouragement and identity affirmation; and belonging and trust illustrate linking capital by establishing legitimacy and confidence in institutional pathways (Glass, 2022; Putnam, 2000; Tuominen et al., 2023).

The findings suggest that technical training alone is insufficient; equitable pathways into cybersecurity require intentional cultivation of relationships and

trust. Programs that emphasize mentorship, peer cohorts, and community engagement better equip students of color to persist (McGee, 2020). For practitioners, this means designing programs with structured mentorship, cultural responsiveness, and sustained community partnerships. For policymakers, it means incentivizing collaborations, requiring equity-focused accountability measures, and embedding diversity mandates into workforce frameworks such as NICE (Cybersecurity and Infrastructure Security Agency, 2023).

By applying social capital theory, this study highlights that equity in cybersecurity workforce development depends not only on "opening doors" but also on ensuring that students have the networks, trust, and legitimacy to walk through them and thrive. This finding aligns with broader research on STEM diversity, which emphasizes the importance of supportive environments and inclusive practices (Estrada et al., 2016).

Conclusion

This research examined how cross-sector collaboration supports students of color in cybersecurity, guided by social capital theory. Findings revealed that collaborative programs expand access, provide networks of support, and build belonging and trust, mapping onto bridging, bonding, and linking social capital. The study underscores that student engagement is not solely a matter of technical skill acquisition but is deeply rooted in relational capital. Without intentional design to build social capital, students may have access to opportunities but lack the trust, support, and identity affirmation to persist.

For practitioners, the implication is clear: collaborations must foster mentorship, cultural responsiveness, and community engagement. For policymakers, the findings highlight the need for equity-focused funding, accountability mechanisms, and integration of diversity into national workforce frameworks (National Science Foundation, 2023). Ultimately, addressing the cybersecurity workforce shortage requires moving beyond pipeline expansion toward creating relationally grounded pathways. By centering social capital, cross-sector collaborations can ensure that students of color are not only included but are empowered as engaged contributors to the future of cybersecurity.

The following are recommendations for organizational leaders and policymakers who want to use social capital (bridging, bonding, linking) to help close the cybersecurity workforce gap and increase participation by students of color:

Paid Apprenticeships and Internships

Invest in paid, credit-bearing apprenticeships and internships tied to academic pathways to create linking and bridging capital. Paid, structured apprenticeships and internships create institutional links to employers (linking capital) while opening access to opportunity across social boundaries (bridging capital). Evidence

shows Registered Apprenticeship and employer-sponsored apprenticeship models expand access and produce hireable talent, and program playbooks explain how to attach apprenticeships to campus pathways (HBCUs/MSIs included) (ApprenticeshipUSA, 2023). Organizational leaders and/or policymakers may fund pilot Registered Apprenticeship cohorts with employers and local HBCUs/MSIs and ensure to guarantee wage support for apprentices in order for low-income students to participate (Rutgers-New Brunswick, 2025). Possible short success metric could be a percentage of apprentices from underrepresented groups who complete these programs and receive a job offer within 6 months.

Establish culturally responsive mentor networks

Require mentor cultural and diversity awareness training to strengthen bonding and linking capital. Research shows students of color prefer mentors who acknowledge race and provide culturally responsive support; mentor representation ("mirror mentoring") increases engagement and retention. Mentors who are trained to recognize cultural contexts produce better outcomes for underrepresented mentees (Vierra et al, 2024). Organizational leaders and policy makers can launch formal mentorship programs that pair students with multiple mentors to include industry professionals, near-peers, and faculty to create diverse developmental networks; expect each mentee to have at least one near-peer and one industry mentor.

Create cohort-based learning communities and near-peer programs

Designing entities with the intent to strengthen bonding capital, which may improve retention. Cohorts, peer networks and near-peer mentoring create dense bonding capital that improves persistence, confidence, and academic outcomes for underrepresented students in STEM pathways. Studies show cohort models and active developmental mentor networks increase support and aid transitions (Pedersen et al, 2024). Organizational leaders and/or policy makers can create funding opportunities for semester-long cohort cohorts that may include bootcamps, course blocks, and peer mentoring for students recruited from targeted communities; pair cohorts with an industry partner for project work to add bridging capital.

Leverage community partnerships and family engagement

Expand outreach and reduce access barriers in order to activate bridging capital with these forms of partnerships. Community organizations and family engagement create trusted routes into programs for youth of color, helping information and resources cross social boundaries in respect to bridging capital. Research and program evaluations show that partnering with community groups, K–12 schools, and trusted nonprofits increases recruitment diversity and program uptake (Ismail et al, 2024). Organizational leaders and/or policy makers can look to require grant proposals for workforce programs to include community partner

letters and parent/guardian outreach strategies to establish workshops, flexible scheduling, and transportation/childcare support.

Measure social capital

Seeking to make funding contingent on clear social-capital outcomes to move from good intentions to impact, programs must measure how they create bridging (access), bonding (support networks), and linking (institutional trust/opportunity). Recent measurement frameworks and reviews give instruments and indicators for each social-capital dimension so leaders can evaluate what works and scale evidence-based models (Allen et al, 2021). Organizational leaders and/or policy makers can seek to require grantees to report standardized social-capital indicators (examples: number of industry contacts per student; mentor network size and diversity; proportion of participants with at least one paid work experience; measures of belonging/trust using validated scales).

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The author declares no conflict of interest.

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