

Leveraging Social Capital to Broaden Participation in STEM

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Abstract

Broadening participation in science, technology, engineering, and mathematics (STEM) is critical to the nation's economic growth and national security. In K–12 and higher education, researchers and educators increasingly employ the concept of social capital to develop programs for improving STEM learning, motivation, and participation of young students. STEM social capital in education comprises STEM-oriented resources—whether instrumental, informational, or emotional—that students access through their social networks. Major theoretical perspectives, research evidence, and promising practices are associated with the concepts of social capital in STEM education. Students' social capital in STEM education (derived from families, peers, teachers, and professional networks) demonstrably promotes their STEM educational outcomes and career paths. Inclusive STEM schools, mentoring, and after-school programs are some promising approaches that can enhance STEM social capital and outcomes of underrepresented students, particularly women, Blacks/Hispanics/Native Americans, youth with low socioeconomic status, and persons with disabilities.

Keywords

social capital, STEM participation, families, peers, teachers, professional networks

Tweet

STEM-oriented social relationships and support—whether instrumental, informational, or emotional—among young students, especially underrepresented groups, can broaden participation in STEM.

Key Points

- Social capital in STEM education is a resource—whether instrumental, informational, or emotional—that students access through their social networks, which can promote their STEM educational and career outcomes.
- Students's STEM social capital breaks down into two dimensions, that is, bonding (strong ties) versus linking (weak ties, a special type of bridging), and two forms, that is, structural (networks) versus cognitive/affective (subjective support).
- Students' social capital in STEM education—derived from families, peers, teachers, and professional networks—promotes their STEM educational and career development.
- Promising policies/programs/practices such as inclusive STEM schools, mentoring, and after-school programs can improve STEM social capital and outcomes of underrepresented students.

Introduction

In the United States, an increasing workforce demand for college-educated professionals in science, technology, engineering, and mathematics (STEM) has created a pressing need to recruit and retain more young students in STEM-career paths. According to the U.S. Bureau of Labor Statistics (2019), STEM occupations are projected to grow by 8.8% from 2018 to 2028, compared with a 5.0% growth for non-STEM occupations. Granted, not all STEM occupations face labor supply issues, due to the large number of new entrants and large share of immigrants recruited for given occupations (such as computer programmers and electrical/electronics engineers). Still, many STEM professions are at high risk of labor shortages, particularly in cybersecurity and in several engineering fields including biomedical, civil, and environmental engineering (Levanon et al., 2014).

Coupling with the anticipated labor shortages in certain STEM subfields, the issues of inequitable access to STEM education and professions continue to be of significant concern. National statistics consistently show that women,

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Blacks/Hispanics/Native Americans, youth from low socioeconomic status (SES) backgrounds, and persons with disabilities are severely underrepresented in STEM education and occupations (National Science Foundation [NSF], 2019). The lower rates of STEM participation for these social groups can be traced to their lower levels of interest in STEM subjects and careers since adolescence. Young women, Blacks and Hispanics (or underrepresented racial/ethnic minorities [URM]), and low-SES students reported considerably lower levels of career interest in STEM upon entering and toward the end of high school, in a recent national longitudinal study (Saw et al., 2018). Nationally, only about one out of ten high school freshmen was interested in pursuing a career in STEM, and that rate declined as students progressed through high school. This is alarming as STEM-career aspirations in adolescence are one of the primary determinants of pursuing a college degree and entering a STEM profession (Legewie & DiPrete, 2014; Tai et al., 2006).

To address the challenges of STEM workforce development and STEM diversity, public and private institutions have launched various STEM educational initiatives at the national, state, and local levels (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016; National Research Council [NRC], 2011, 2015). In 2016, for instance, the White House launched a four-billion dollar Computer Science for All (CS for All) initiative to improve computer science education in K–12 schools. Many corporates such as Apple, Facebook, and Microsoft have also joined the national “CS for All” effort (Smith, 2016). Researchers in education and behavioral sciences have also been investigating the sources of and solutions for STEM skills gaps and disparities, and to experiment with different interventions for strengthening STEM educational and career pathways of young students, particularly among underrepresented groups (see reviews by Cromley et al., 2016; Liben & Coyle, 2014; Xie et al., 2015).

Among other theoretical perspectives, the concept of social capital has been increasingly employed by researchers and practitioners in STEM education to understand and design new programs/practices for enhancing students’ STEM learning, motivation, and participation (e.g., Archer et al., 2012; Habig et al., in press). Social capital is a resource accessed through social networks (Bourdieu, 1986; Coleman, 1988; Putnam, 2000). Students’ social capital derived from family, peer, and school contexts affects their academic achievement and career trajectories (e.g., Coleman, 1988; Dika & Singh, 2002; Kim & Schneider, 2005; Morgan & Sørensen, 1999; Ream & Rumberger, 2008; Ryan, 2017). In her presidential address at the 2013 National Association for Research in Science Teaching (NARST) annual conference, Dr. Sharon Lynch advocated for reform initiatives, such as inclusive STEM schools (ISTEMSs), that help expand STEM social capital of underrepresented students (NARST, 2013). NSF has also recently funded several innovative multiple-year projects that apply the concept of social capital to

study and enhance STEM outcomes of underrepresented students in K–12 and higher education.

Despite growing interest in and use of social capital for improving STEM education and participation, a comprehensive review of the research on social capital in STEM education is notably absent. Such a review will assess the existing evidence and offer policy insights into utilizing the concept of social capital to effectively target resources and develop programs that can improve STEM education and diversity.

This article takes up this task and serves three purposes. First, building on prominent theoretical perspectives of social capital, it formulates a conceptual framework for guiding the review of social capital research and practice in STEM education. Second, it reviews the extant evidence on the associations between social capital and student outcomes in STEM education. Third, it provides recommendations for policy, practice, and research on applying and expanding the idea of social capital for designing and testing interventions on strengthening STEM educational and career pathways.

A Conceptual Framework of Social Capital in STEM Education

In recent decades, social capital has proved useful in sociology, political science, economics, and education (Engbers et al., 2017), but without agreeing on one definition. Bourdieu (1986) described social capital as a resource available to an individual based on group membership, relationships, networks of influence, and support. Coleman (1988) explained that social capital inheres in the structure of relations and can be valuable in facilitating certain actions that lead to desirable outcomes. Putnam (2000) regarded social capital as social networks with value; these social contacts affect the productivity of individuals and groups.

In the context of education, STEM social capital comprises students’ resources accessed through their social networks that can promote STEM educational and career outcomes. Social capital has received widespread attention in social science and increasing attention among STEM education research. Because comprehensive reviews of social capital theories are already available (e.g., Adler & Kwon, 2002; Bhandari & Yasunobu, 2009; Hawkins & Maurer, 2012), rather than repeating previous efforts, this article first discusses some major definitions of social capital (particularly its dimensions, forms, and levels). Afterward comes a proposed integrated conceptual framework of social capital applicable to STEM education. All this analysis culminates in policy suggestions.

Dimensions of Social Capital: Bonding Versus Bridging (Including Linking)

While disagreements persist, most theorists agree that the concept of social capital can be deconstructed into two major

dimensions: bonding and bridging (Portes, 1998; Putnam, 2000). *Bonding social capital* refers to horizontal social relations and norms that build on *similarity*, informality, and intimacy, developing “strong ties” and connections within the group. It typically develops among families, close friends, and those individuals who share similar characteristics such as age, race/ethnicity, or education (Putnam, 2000). *Bridging social capital* describes formal and informal horizontal relations and norms among *diverse* individuals that form “weaker ties,” for example, people of different demographic backgrounds (Halpern, 2005). In addition to bonding and bridging social capital, which refer to *horizontal* social relationships, *linking social capital* has been proposed to describe *vertical* but weak ties that connect people across different hierarchical positions, constituting a mix of formal and informal links (Ferlander, 2007; Woolcock, 2001). Linking social capital can be seen as a “sub-dimension” of bridging social capital because both of them refer to ties that cut across different groups. Some scholars described linking social capital as access to professional resources (e.g., personally knowing a lawyer or physician), as it enables people to access resources and information outside their social network (Dahl & Malmberg-Heimonen, 2010; Field, 2003).

The definitions of social capital, with respect to the two dimensions of bonding and linking (a specific type of bridging), offer a useful theoretical lens for understanding and measuring STEM social capital among young students. For example, participating in a STEM summer program that connects peers who share a similar interest in STEM could illustrate bonding social capital in STEM education, whereas meeting with and having informational support from STEM professionals at an out-of-school event or program illustrates linking social capital in STEM education.

Forms of Social Capital: Structural Versus Cognitive

Most conceptualizations of social capital include two forms: one structural and the other cognitive/affective. The *structural* form includes the extent and intensity of associational links or activities that facilitate sharing resources, whereas the *cognitive/affective* form covers the subjective perceptions of support, trust, and social norms. While some theorists (e.g., Bourdieu, 1986; Woolcock, 1998) view the structural social network as the core form of social capital, others regard its content—the cognitive/affective forms of social capital—as crucial to the concept (e.g., Putnam, 1993; Wellman & Frank, 2001). Arguably, the network would collapse without the social cohesion or reciprocal norms. Nevertheless, most scholars regard social capital as a combination of both structural and cognitive/affective forms (Ferlander, 2007; Putnam, 1995). Therefore, analyzing both structural and cognitive/affective forms of social capital

helps to understand how social capital manifests, operates, and maintains itself.

In the context of STEM education, membership in an after-school STEM club could illustrate structural social capital, whereas parents having high expectations (norms) for STEM learning can illustrate cognitive social capital. By integrating these two forms of structural and cognitive/affective social capital with the two dimensions of bonding and linking social capital, this article proposes a novel, two-dimensional conceptual framework for characterizing social capital in STEM education (see Figure 1). This framework could facilitate theoretical discussions, empirical research, and practical applications of social capital in STEM education.

Social Capital Benefits STEM Education: Evidence

Guided by the conceptual framework just developed, this section reviews existing research on the relationships between social capital and student STEM outcomes, including achievement, motivation, and college attainment in STEM areas. This article organizes the multiple types of social capital in STEM education by the dimension and form primarily studied: (a) bonding-structural, (b) bonding-cognitive/affective, (c) linking-structural, and (d) linking-cognitive/affective. Three sources of relevant evidence are reviewed: (a) studies on STEM-specific social capital, (b) studies of social capital on STEM outcomes, and (c) social capital studies of students in STEM education. Studies reviewed in this article involve life stages from young students at the middle school level to adult students in undergraduate and graduate degree level (excluding social capital studies in STEM workplaces with the samples of K–12 teachers, university faculty, and working professionals).

Bonding-Structural Social Capital

Bonding-structural social capital in STEM education reflects whether and how being embedded in a formal or informal social network or group that builds on *similarity* can enhance individuals’ learning and engagement in STEM. Such networks or groups typically develop among families (with parents and siblings), close friends, and peers who share similar characteristics or are present in the same venue such as classrooms. For example, taking Advanced Placement (AP) computer science in school or attending a space astronomy program during summer time offers an opportunity for a high school student to expand peer network that shares similar interest in a particular STEM subject or career, which could in turn promote their STEM learning, motivation, and participation.

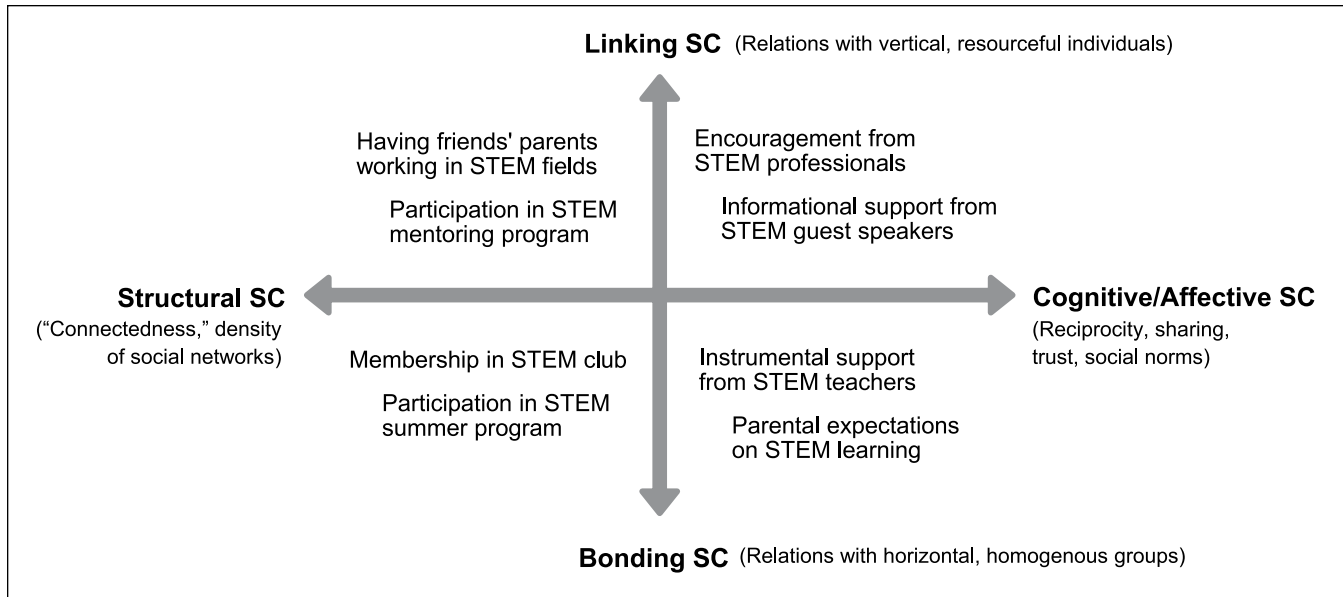


Figure 1. A conceptual framework of social capital in STEM education.

Note. SC = social capital; STEM = science, technology, engineering, and mathematics.

The benefits of bonding-structural social capital in STEM are well-documented in the research. For instance, in course transcript data from the Adolescent Health and Academic Achievement Study (AHAA), high school female students were more likely to take more advanced level math courses in the year after being enrolled in a course with other same-sex peers who have taken higher level math coursework (Frank et al., 2008). In the Swedish subset of the Children of Immigrants Longitudinal Survey in Four European Countries (CILS4EU), students' favorite subjects were influenced by friends' preferences (friend influence) and classroom peers' preferences (peer exposure; Raabe et al., 2019). Specifically, exposure to female classmates who have a STEM-favorite subject has a strong positive effect on girls' individual STEM preferences (Raabe et al., 2019).

Apart from classmates or friends in school, STEM teachers represent another aspect of bonding-structural STEM social capital every student accesses in daily life. However, not all STEM teachers are equal. Students form stronger social relationships with their STEM teachers who share similar characteristics, such as sex, race/ethnicity, and residential neighborhood. Such STEM teacher–pupil relationship may enhance students' learning and interests in STEM. Longitudinal data from public school students in North Carolina indicated that young White women's likelihood of enrolling and completing a postsecondary STEM degree program increased if they came from high schools with higher proportions of female math and science teachers, irrespective of teacher race/ethnicity (Stearns et al., 2016). Similar positive effects of STEM teacher–student characteristics match were also documented in the data from postsecondary

education institutions, in which Black students were more likely to major in STEM fields if they had a Black instructor for a STEM course (Price, 2010; Rask & Bailey, 2002).

Bonding-Cognitive/Affective Social Capital

While bonding-structural social capital focuses on social networks or group memberships, bonding-cognitive/affective social capital emphasizes actual and subjective perceptions of support, reciprocity, trust, and social norms within a network or group with members of similar characteristics or close ties—families, friends, teachers—potentially related to individuals' performance and outcomes. For youth, indicators of bonding-cognitive/affective social capital in STEM are, for example, perceived acceptance or informational support by peers in STEM classes or after-school programs, academic expectations or instrumental support from their STEM teachers, and parental involvement or emotional support in the context of STEM education.

Peer support and interactions with academic instructors are valuable bonding-cognitive/affective social capital for young students in formal and informal STEM learning. For instance, in interviews of 66 alumni of the Land Science Program (a 7-year program with a minimum of 165 contact hours per year offered by the American Museum of Natural History in New York City), youth who participated in the program formed enduring relationships with their interest-sharing peers that persisted beyond the program and supported them to navigate their college and career trajectories in STEM (Habig et al., in press). In the higher education context, a large sample of community college freshmen in

STEM courses showed—for older students (30 years old or above)—moderate engagement in learning network with peers and discussions with academic advisors related to the least dropout (Wang et al., 2018).

Other than peer support, parental involvement supplies critical bonding-cognitive/affective social capital in education (e.g., Coleman, 1988; McNeal, 1999; Perna & Titus, 2005; Ryan & Ream, 2016). At least four aspects of parental involvement can affect students' academic and career trajectories: (a) parent-child discussion, (b) monitoring, (c) parental networks (or intergenerational closure), and (d) parent-teacher interactions. In a sample of high school students, parental involvement in science education *at school* was positively associated with students' science grades and self-efficacy, whereas parental involvement *at home* positively related to students' interest and perceived value in science, as well as time spent on science homework (Shumow et al., 2011). For middle school students in Israel, perceptions of the goals that parents and teachers emphasize were related positively to students' motivation for science learning (Vedder-Weiss & Fortus, 2013).

Linking-Structural Social Capital

Unlike bonding-structural social capital—social networks or groups building on *similarity* or shared characteristics—linking-structural social capital in STEM education connects individuals across positions in different hierarchies. Linking-structural social capital, either in formal or informal learning environments, could promote student STEM outcomes. In practice, many educational initiatives to enhance linking-structural STEM social capital among students, especially those underrepresented in STEM, do often help expand students' social networks outside their families, school teachers, and peers (Brewington et al., 2019). Students' networks could extend to include STEM professionals or individuals with knowledge or relationships necessary to be successful in navigating educational and career pathways in STEM (such as STEM academic counselors and undergraduate/graduate students in STEM fields).

Meeting or knowing adults or older peers in STEM fields of study and occupations could provide opportunities of vicarious experience or role models for students who have no family members working in STEM fields, which could promote their career interest in STEM. In a large diverse sample of middle and high school students (including 55% girls, 65% URM, and 53% low-income students whose parents did not completed college) taking part in a 7-week STEM summer program in San Antonio, Texas, students who reported knowing more STEM professionals after attending the summer program had increased interest of pursuing a career in STEM fields (Brewington et al., 2019; Saw et al., 2019). In a recent meta-analysis, connecting or exposing students (from middle school to college level) to STEM professionals who share the same social identity in terms of sex and race/ethnicity (called *ingroup role model*) has a positive effect on

performance and interest of female and URM students (Lawner et al., in press). This particularly held for programs conducted in field settings with longer contact hours, as opposed to brief contacts in laboratory settings (Lawner et al., in press).

Linking-Cognitive/Affective Social Capital

While linking-structural social capital emphasizes the relationships of extended networks and individuals' outcomes, linking-cognitive/affective social capital in STEM addresses subjective perceptions of support from and actual interactions with people who are external to immediate networks but—with higher status and greater access to resources (such as professional information; Dahl & Malmberg-Heimonen, 2010; Lin, 2001)—can improve student STEM outcomes. Once connected with knowledgeable and resourceful individuals, students may receive crucial support for success in STEM education and career paths. The support could be informational, instrumental, or emotional. Internship and mentoring programs are common practices for securing and expanding linking-cognitive/effective social capital in STEM education for young students, especially those who are from underrepresented groups, including women, URM, low-SES students, and persons with disabilities.

Both quantitative and qualitative evidence support the benefits of mentorship and faculty-student interactions on student outcomes. This particularly holds for undergraduate and graduate STEM programs, where mentoring is an integral component of studies. In a longitudinal ethnographic study with 15 successful women of color in STEM professions, the development of a strong scientific identity related to the interactions with faculty when in undergraduate degree programs (Carlone & Johnson, 2007). STEM undergraduate research programs also benefit from interactions with faculty or research mentors, which help socialize students, particularly women and URM, into STEM fields (e.g., Hunter et al., 2009; Thiry & Laursen, 2011). For a national sample of undergraduate life science researchers, both receiving mentorship from postgraduates and interactions with faculty positively associated with science identity, self-efficacy, and perceptions of career readiness (Aikens et al., 2016).

STEM Social Capital in Action: Promising Reforms

Over the past two decades, the number of STEM-focused schools has been continuously growing across the globe (Choi, 2014; Means et al., 2008; Tan & Leong, 2014). Selective or elite schools were the traditional model of STEM-specialized schools serving primarily gifted and talented students (Thomas & Williams, 2010). In addressing the critical issues of STEM equity and diversity, a new movement of establishing STEM-focused schools aimed at broadening access to specialized STEM education for underserved

and diverse student groups has begun to develop (Means et al., 2008; Talaue, 2014). In the United States, ISTEMSs—which combine nonselective admission policies with a STEM-emphasized curriculum and college-going/career counseling structure—are an emerging model, rapidly expanding across the nation, particularly in the states of Texas, North Carolina, and Ohio (Gnagey & Lavertu, 2016; Means et al., 2017).

ISTEMSs represent a promising reform in STEM education theoretically links to the social capital (Lynch et al., 2018). These schools aim to improve student performance in STEM-related subjects and to increase the number of students pursuing a postsecondary degree and career in STEM disciplines, especially those from underrepresented groups. Despite variation across campuses, ISTEMSs generally implement a rigorous curriculum and provide academic support in STEM subjects (LaForce et al., 2014; Lesseig et al., 2019). Most ISTEMSs also develop college-going/career counseling structures and partner with postsecondary and industry organizations to offer internships or mentoring programs to prepare students for entering a postsecondary education program and career in STEM professions (Lynch et al., 2014; Means et al., 2018).

By bringing a large number of underrepresented students—who are women, URM, and low-SES students—to STEM-emphasized schools, ISTEMSs provide opportunities for students to enhance their bonding-structural and bonding-cognitive/affective social capital in STEM education through extending and engaging in a network of peers who share similar social identities and interest in STEM. Through opportunities of interacting with and receiving mentorship from mentors and resourceful individuals in STEM fields, ISTEMSs connect students to a larger community of STEM professionals, expanding students' linking-structural and linking-cognitive/affective social capital in STEM education. To date, limited, but growing, evidence suggests that ISTEMSs could be effective in promoting positive student outcomes in STEM, including STEM-career interest, advanced STEM coursework completion, and enrollment in postsecondary STEM degree programs, especially among underrepresented groups (Means et al., 2017, 2018; Saw, 2019).

Implications for Policymakers and Educators

Overall, a growing research base suggests that social capital is a promising theoretical concept to be utilized more widely for designing policies/programs or to inform practices to increase and broaden participation in STEM. From the perspectives of bonding-structural and linking-structural social capital, policy initiatives and programs aimed at enhancing opportunities for students to connect and engage with more interest-sharing peers and professionals in STEM fields could help them develop extended social networks that can

support their educational and career pathways in STEM. ISTEMSs represent one of the latest comprehensive school-wide reform models that offer opportunities for students, particularly underrepresented groups, to participate in a STEM-specialized learning environment with interest-sharing peers. In out-of-school settings, offering after-school or summer programs, such as robotics team or science summer camp, can foster peer networks and pair students with STEM mentors. These out-of-school time programs are practical social capital building strategies that can reach a large number of students across the country, especially in rural communities (Afterschool Alliance, 2016).

From the perspectives of bonding-cognitive/affective social capital, policymakers and educators can develop and expand programs that promote STEM-oriented interactions among peers and parental involvement in STEM education both at home and at school. Creating and supporting STEM-focused clubs or study groups, in and out of school, is one approach. An alternative way is to introduce STEM-related materials or activities to the existing well-established student organizations such as Girl Scout STEM Programs and Young Men's Christian Association (YMCA) STEM Programs. To promote parental engagement in STEM, they must have expanded access to STEM learning resources and activities, especially for those parents without a college degree and those who are not working in STEM fields. Equally important is providing training and professional development in STEM for educators and social service providers, such as public librarians or museum staff, whose tasks involve engaging parents in their children's learning activities.

Policy initiatives informed by linking-cognitive/affective social capital could strengthen the informational, instrumental, and emotional support in STEM education, especially for women, URM, low-SES students, and people with disabilities, by promoting their learning and interactions with experienced educators or professionals in STEM. One common effective method is to create and facilitate well-designed mentoring programs that pair students with STEM educators or professionals who are knowledgeable and passionate about supporting students' educational and career development. Training and supporting those STEM educators or professionals in providing mentorship can help them be effective mentors for their mentees. Also helpful is partnering schools with industry organizations to offer internships for students to shadow professionals in real-world STEM settings.

Conclusion

Policymakers, corporate leaders, educators, scholars, and the general public prioritize increasing and broadening participation in STEM. Many policy initiatives and educational reform programs have also launched with encouraging results. However, STEM labor shortages and disparities continue to be a great concern in the United States and many

other countries. Here, a summary of theoretical perspectives, research evidence, and promising practices associated with the conceptions of social capital in STEM education aims to stimulate further research. This essay also aims at encouraging policy and practice that can improve STEM education and workforce development, while promoting equity, diversity, and inclusion in STEM.

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