

Board 288: Exploring the Importance of Bonding and Bridging Capital for Graduate Women Accessing Academic and Professional Pathways in STEM

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Introduction

The benefits of a graduate education are well documented and have significant implications for economic growth, equality, and social mobility [1]. Still, women remain underrepresented in STEM graduate programs and occupations requiring graduate education, despite representing 50% of the U.S. population [2]. Some literature points to the importance of social networks in broadening participation in STEM fields and supporting student persistence [3], [4]. Within social capital theory are two subtypes, bonding and bridging social capital. Bonding capital encompasses relationships that may provide emotional and helpful support between individuals with similar backgrounds. Bridging capital encompasses relationships outside of an individual's core group, which extend their personal network and aid in the ability to "achieve one's goals" [3, p. 205]. Drawing upon these concepts, the current study sought to understand how graduate women in biology, environmental engineering, and geosciences mobilized bonding and bridging social capital to access academic and professional pathways. Specifically, this case study investigated women in master's programs participating in a National Science Foundation (NSF) S-STEM program and interdisciplinary community of practice, focused on a wicked problem of understanding and balancing biogeochemical cycles in natural and engineered systems, incorporating a variety of strategies (e.g., mentoring, research opportunities, community engagement, coursework) to ease transitions into and through master's programs.

Literature Review

Limited research exists on graduate women in the STEM disciplines. Within the extant literature, we found that women were less likely to apply to graduate school than men, and access to social capital plays an integral role in that decision. Of the women who attend graduate school, developing relationships with colleagues within and outside research groups can be beneficial to their success. Additionally, faculty interactions can lead to stronger professional identities and networks.

The Experiences of Graduate Women in STEM

Master's programs present an important transition from undergraduate to graduate STEM education. Though women make up 47% of master's students in science and engineering, they comprise a larger proportion in science than engineering [5]. While there tends to be low representation of women in engineering disciplines overall (28% at the graduate level; [6]), engineering students in the current study were primarily from the environmental engineering discipline, which has a larger proportion of US women graduate students (42% at the MS level; [7]). Some insights can be gained by looking at differences between men and women at the graduate school application stage. Baker et al. [8] found that while 69% of high achieving (3.5 GPA) male engineering seniors planned to apply to graduate school, only 32% of high achieving women seniors were planning to apply. Reasons women students cited for not applying to graduate school included the "chilly climate" in male dominated engineering programs, lack of

knowledge about the process of applying to graduate school, lack of encouragement and reticence about asking faculty for letters of reference or research opportunities. Women students who applied to graduate school were more likely to be motivated by intrinsic factors (e.g., love of learning, interest in their field) than male students, who were more motivated by furthering their careers. The authors noted that personal outreach and encouragement to apply to graduate school were more important influences on women's decision making than men.

Once they transition into graduate education, women contend with experiences of sexism, gender stereotyping, delegitimization, and isolation [9]. To mitigate these challenges, women often have to depend on their own resilience and capacity to cope with these conditions. In a qualitative study investigating factors that contributed to the persistence of women graduate students and early career professionals, researchers found that women's abilities to rebound after failures and a willingness to assert themselves when confronted by sexist colleagues was integral to their success [9]. Salient to the current study, women who persisted in the field cultivated networks of supportive colleagues both inside and outside their research groups and departments [9]. Despite the challenges women graduate students encounter, completion of masters' programs can broaden career opportunities and support their access to and success within STEM doctoral programs [10]. However, due to the scope of a quantitative study, the researchers were unsure of what factors contributed to successful outcomes of minoritized students who completed a master's degree prior to entering doctoral education [10]. Thus, the current study explores how women in STEM masters programs harness bonding and bridging social capital to access academic and professional pathways. In the next section, we discuss the literature that focused specifically on the role of social capital in graduate education.

Role of Social Capital in Graduate Education

There is a persistent disparity in graduate education for historically underrepresented people, but particularly dire is in the STEM disciplines [11]. Many researchers focused on increasing diversity in graduate education emphasize the need for students to understand the norms and expectations in academia as a form of socialization, to transform from student to scholar [12], [13]. There are multiple ways in which social capital has an impact on pursuit of graduate education, including access, equality in support (emotionally, financially, academically), mentorship, and feelings of belonging during transition. If a student is traditionally underrepresented in graduate education, the strength of their social capital may be the deciding factor in their pursuit of graduate education [[14]-[17]. Social capital plays a role in academic and professional success and identity formation [18]. The creation of opportunities for students to socially interact with faculty during their time pursuing postsecondary education facilitates social capital the students can then use to network and develop their sense of professional identity [19]. Additionally, networking in graduate education is related to increased employability due to increased access to available resources [20].

Conceptual Framework: Bridging and Bonding Capital

We applied bonding and bridging as an analytic framework in this study. Bonding and bridging capital are constructs situated in social capital theory. Social capital theory is the overarching idea that social relationships can benefit the individual in numerous ways [21]. Networking and relationships allow the individual to gain access to knowledge and opportunities shared by the

network. Numerous scholars have used, criticized, and reinterpreted social capital theory [22]. For example, Harper [23] noted that some researchers fail to recognize the capital possessed by minoritized groups, including women and communities of color, in their scholarship. Though Bourdieu's [24] groundbreaking work showed society values some forms of capital as more esteemed than others, educators and scholars assumed this to mean some forms of capital are not worth possessing, or do not exist [25]. Bonding and bridging capital have been overlooked as impactful forms of capital for minoritized groups [19]. As previously mentioned, bonding capital includes the shared values and resources that an individual gains by being in relation with members of a group (e.g., S-STEM intervention program) [26], [27]. However, bridging capital involves connections made possible by members in a core group [3]. Core group members such as faculty advisors would initiate these relationships either directly or indirectly. Direct ways could be introducing a student to a prospective employer. An indirect approach would consist of hosting events or programs where students learn about the work of professionals in the field, and a student following up with that professional later. In previous research, these concepts have been utilized to investigate the impact on identity formation in the academy for students who come from low socioeconomic (SES) backgrounds [19] graduate employability [28], and the role of capital in the persistence of engineering Latina/o students [3]. These studies show the utility of exploring bridging and bonding capital in contributing to students' positive academic and professional outcomes. To this end, we used bonding and bridging capital theory to understand how graduate women in an S-STEM program accessed professional and academic opportunities.

Methods

Study Context

This study investigated how social capital influences the experiences of 12 women in master's programs participating in a National Science Foundation (NSF) S-STEM program. The S-STEM program is centered on the wicked problem of understanding and balancing biogeochemical cycles in natural and engineered systems. Managing these cycles has been identified as a Grand Challenge by the National Academy of Engineering. The S-STEM program engages students in an interdisciplinary approach to managing nitrogen that incorporates biology, geosciences, and engineering. The program integrated research opportunities, community engagement, coursework, and faculty and peer mentoring strategies to support student success. S-STEM scholars engage in biweekly meetings that include roundtables with scientists and engineers from academic, government and industry. Students also engage in presentations of their own thesis projects, writing workshops, and discussions with community partners.

Participants

Twelve graduate women students participated in this study. Although the program focuses on STEM broadly, our participants account for graduate women students who were pursuing their master's degrees in biology, environmental engineering, and geosciences. In Table I, we present the participant demographics.

TABLE I
PARTICIPANT DEMOGRAPHICS

Pseudonym	Major/Discipline	Race/Ethnicity
Caitlin	Conservation Biology	White
Catalina	Geology	Hispanic/ Puerto Rican/ Italian
Emily	Environmental Engineering	Chinese, born in Vietnam, immigrated to US <1 yr old
Jennifer	Quantitative Ecology	White
Jessica	Environmental Engineering/ International Development	Unknown
Julieta	Environmental Engineering/ International Development	Mexican American
Kelly	Biology Education	Caucasian
Kenzie	Integrative Biology	White
Maria	Environmental Engineering	Mexican American
Michelle	Environmental Science and Policy	White/Caucasian
Molly	Biology/ Ecology and Evolution	White
Ramsey	Environmental Engineering/ International Development	Unknown

Note: We provide self-reported race and ethnicity according to participants' preferences.

Data Collection Procedures

Data sources included semi-structured interview data and participant observations at roundtable workshops used to examine this phenomenon. We conducted semi-structured, one-on-one, 60-minute interviews during the spring semesters of 2021 and 2022 with program participants who consented to participate in the study. The interview protocol entailed questions about participants' backgrounds; experiences with S-STEM advising, mentoring, and professional

development; and experiences with project activities (e.g., roundtables, alumni interactions, community engagement activities). Additionally, we conducted participant observations at roundtable workshops during the fall and spring semesters from 2020-2022. Roundtable workshops were 60 minutes in duration. We documented notes about discussions or activities that took place in the workshop every 12-15 minutes. We noted who was speaking, what was being discussed, how these activities related to the goals of the programs, and how these activities answered our research questions.

Data Analysis Procedures

We audio recorded interviews and then transcribed by a third-party verbatim. To begin the data analysis process, as a team, we read three transcripts and applied an open coding technique using participants words and phrases to generate codes [29]. We also generated a list of a priori codes taken from concepts in the literature, our interview questions, and program activities. These codes were transferred to a codebook consisting of codes, definitions, and exemplar quotes [30]. After which, all transcripts and the codebook were loaded into Dedoose for focused coding using the open and a priori codes we developed. Our next phase of the data analysis process entailed axial coding [31]. Axial coding allowed us to identify superordinate and subordinate codes. For example, bridging capital is a superordinate code, and subordinate codes may include academic support and professional development. From these codes, we may uncover that a participant receives academic support from S-STEM program peers and professional development resources from S-STEM program faculty. This information is then leveraged to bridge their capital to resources, services, and goods outside of the program. This may entail following up with program speakers to secure an internship or connecting with a researcher in the field to better understand a problem that emerges in the lab. In the next section, we share the results that emerged from our analysis.

Results

An analysis of the data revealed participants leveraged relationships cultivated in the S-STEM program to strengthen their bonds with faculty and peers. These relationships also enabled participants to bridge their capital through making connections with individuals external to the community in order to meet academic and professional goals. Some of these relationships began prior to enrolling in graduate school. For example, some participants had existing relationships with S-STEM faculty that resulted in their capacity to access graduate education. Though some participants reported being intentional about engaging in undergraduate research, as a means to build relationships with faculty and apply their disciplinary knowledge, their pathways to master's programs were less directed. It often included chance encounters with faculty members, who served as institutional agents, explaining admissions processes, and helping participants identify practical and financial support to attend graduate school.

I really didn't think too much about what school I was going to go to. I was attending a conference with one of my professors in undergrad, and I had mentioned my interest in international-related issues to her. We were at a water conference. And she's like, "Have you ever heard of this program at [S-STEM institution]? They have an international development program where you do some portion of your research in another country

and then you focus your thesis on that." And I hadn't heard of it. And that was kind of around the same time that the company I was interning for had put the idea in my head about getting a master's. So it was really my professors in undergrad who kind of gave me [direction] towards the school I was going to end up going to. (Jessica)

Once participants became engaged in the S-STEM program, either during the admissions process or while in graduate school, participants noted benefiting from the financial, socioemotional, academic, and professional support necessary to persist in graduate school and prepare for future careers. Two participants explained,

I feel like I have a toolkit now of resources to use, and contacts networking with other professionals; making connections; and resources for writing, interviewing, and other professional development items. It's just like this wealth of knowledge, and it's pretty amazing just meeting for one hour, twice a month, how big of an impact and how much we are exposed to. It's really great. And the students who are in the program, a lot of us are part of group chats and share things. (Jennifer)

I do really love the people in it. Even one of the girls that I saw before COVID just recently reached out and said, "Oh, let's have lunch again." [I see] the students themselves as another opportunity to network, but not just on a professional level, but of what you mentioned with peer networking. I feel like that's a little different than just a professional sense because that can be more of a personal level too. Not to say that professional mentors can't, but I think being with someone who's at the same level as you and that can really kind of speak to what you're feeling in that moment is invaluable. (Kelly)

The bonds participants formed in the program were due in part to the environment faculty and peers created in the program. Participants remarked that program faculty and peers were welcoming, thoughtful, and supportive which contributed to developing strong bonds among members in the S-STEM program. These relationships were also instrumental in participants learning the norms and values of their disciplines as well as gaining the knowledge, skills, and competencies necessary for graduate education. For example, one participant shared,

I ask her [S-STEM faculty mentor] questions about writing. We'll do research. She and I, we're very collaborative. She gives me a lot of input, feedback, helps me build and expand my research, kind of pushed me in directions I never thought I would go. And so I definitely have been challenged, but it's always been something I could handle, and if I couldn't handle, I would email her and be like, "Hey, I need a little bit more clarification. I'm a bit confused in this corner." And she will help me get out of that corner immediately. I've never felt helpless or anything. I've always felt like there's someone I could go to. (Kelly)

Participants also discussed how faculty shared resources with them and opened their networks to them either directly or through roundtable workshops. Access to resources, information, and professionals in the field aided in extending their social network. Thus, these activities cultivated their bridging capital by enabling participants to establish connections with individuals who could support their academic and professional goals in the future. For example, a participant

commented that the roundtables made it easier for her to connect with professionals in field who attended a roundtable session as a speaker,

If I want to reach out to someone, it's easier for me to talk to them first before going to the person, or it's nice to have someone come in and then I feel like, "Oh, I have a connection with them. They gave this talk to us, and now I can ask questions." It just kind of deletes a lot of barriers that would be there. And so, if I can say, "Oh, I'm part of S-STEM program", it's much easier for someone to want to talk to me than a random blank email. And then being able to talk to him is really nice. So, I'm taking his class next semester that I would never have taken if I didn't know about S-STEM. (Michelle)

In sum, the program contributed to the participants' bonding and bridging social capital by facilitating opportunities for mentorship, building relationships among faculty and students, and connecting participants with professionals in the field. Through these activities, participants underscored the value of the S-STEM program in extending their networks as well as preparing them for academic and workforce demands.

Conclusion, Implications and Future Recommendations

The purpose of this study was to examine how graduate women in an S-STEM program mobilize bonding and bridging to achieve their academic and professional goals. Results revealed that S-STEM faculty and peers were instrumental in helping the participants navigate graduate education and prepare for professional trajectories. They were especially useful for understanding the graduate school process, acquiring resources, connecting with professionals in the field, assembling application materials for jobs (e.g., resumes, cover letters), and preparing for job interviews. One participant described the opportunities and information afforded through the S-STEM program as a "toolkit". Furthermore, this study has implications for the importance of using graduate-level scholarship programs as a mechanism to recruit women into master's programs. If undergraduate women in STEM were aware of communities like S-STEM, they may feel more confident about their capacity to succeed and persist in graduate school [9], [14]-[17]. As previous research points, graduate women often have to rely on their own coping strategies to traverse the challenges of STEM graduate education when these networks do not exist [9]. The bonding capital that may also result from participation in an S-STEM program could lead to stronger relationships with faculty and peers. As noted by our participants, these relationships are not only important for meeting academic and career goals, but they are critical to student socio-emotional support especially in high stress environments such as graduate education [32]. Additionally, this study highlights the need to advance intentional practices to ease pathways into STEM graduate education and the occupations. Participants in this study leveraged the bridging capital garnered in the program to acquire information necessary to complete academic tasks such as lab work and continuing their thesis research. Connecting with professionals in the field, who were introduced to participants in roundtable sessions, also proved to be useful in networking for future job opportunities. To that end, future research should explore the outcomes of women graduate students who benefit from bonding and bridging capital provided through S-STEM programs beyond their time in graduate school. While this study investigated women students currently enrolled in a graduate program, a longitudinal study could help to understand the long-term impact of these programs after degree completion.

Acknowledgment: This material is based upon work supported by the National Science Foundation S-STEM Program under Grant No. 1930451. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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