Advancing Women Faculty through Collaborative Research Networks

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Abstract-- The absence of women faculty in the science and technology classroom creates a negative feedback loop that resists change. *Few women want to go to places where few women are*. This paper describes a solution to the conundrum of small numbers. The strategy builds on Sue Rosser's observation that women researchers often respond to a chilly university climate by creating "a small, empowering environment in their own labs" (Rosser 2004). That is, they achieve in microcosm what they are not able to achieve in macrocosm: *functional critical mass*. Social network theory can be applied to achieve functional critical mass. Specifically, universities can generate strategic power for fundamental climate change by enabling and funding a network of interdisciplinary research collaborations among their current women faculty and a few of the women's male peers. By positioning these female-majority research communities in the interstices between disciplinary departments--the "structural holes" in the organizational map--this strategy exploits what sociologist Mark Granovetter (1973, 1983) has called "the strength of weak ties"--that is, information and control advantages of being a broker in relations between people otherwise disconnected in the social structure (Burt 1998).

Introduction

With its metaphor of interconnection, the theme of the 2006 WEPAN National Conference, "Building Bridges," speaks directly to the central issue that faces women faculty in STEM fields: isolation. Despite decades of taskforce recommendations, women scientists and engineers still too often find themselves positioned on islands, disconnected from the mainland of academic life. A five-year self-study published recently by my home institution, the New Jersey Institute of Technology (2005), concluded that being "out of the loop" has a devastating effect on female faculty retention--a conclusion mirrored in dozens of similar studies at universities across the country (*A Study on the Status of Women Faculty in Science at MIT* 1999). Although nearly 90% of the women interviewed in the NJIT study expressed considerable satisfaction with their lives and careers overall, most of them indicated that they had achieved success *in spite of* the institutional culture rather than because of it. For a number of these women, the lack of opportunity for intellectual partnership with their colleagues was especially daunting. Those women who survived often did so by finding collaborators in other departments or at other universities with whom they could do satisfying teamwork.

In this paper, I describe the theoretical research that has led NJIT's Murray Center for Women in Technology to propose a new solution to the problem of female faculty isolation--a proposal embodied in the university's 2005 application for an NSF ADVANCE grant. In the first section below, I discuss how social network theory can be applied to achieve "functional critical mass." I go on to discuss how various networking strategies, including the deployment of pervasive

information technologies, can serve to interconnect small female-majority research communities, to each other and to change agents in senior administration and the external research community. I conclude by describing the third dimension of the NJIT proposal: an assessment strategy that maps networks in research-oriented social space over time. This approach offers universities across the country a dynamic method of measuring institutional climate change.

Defining the Problem

Writing in 1965, Alice Rossi wondered "Why So Few" women achieve success in science and technology. Thirty-three years later, Virginia Valian was still asking the same question--and another, equally vexing question as well: "Why So Slow?" The intervening decades between Rossi's *Science* article and Valian's groundbreaking 1998 book witnessed some progress toward inclusion, but the pace of change has been glacial, especially compared to other professions. In the late 1960's, less than 4% of the nation's lawyers were women; but by 1979 that figure had jumped to 24%, and today a majority of law school graduates are female (Valian 1998). During the same period, women's share of PhD degrees in engineering moved only a few percentage points, from less than 1% in the 1960's to 6% in the 1980's to about 17% today (WEPAN 2006). Women earn nearly half (45%) of the new PhDs in biology but only 27.2% in math and a dismal 13.3% in physics (Nelson 2005). In the familiar phrase, the STEM pipeline "leaks females" at every joint. In high schools today, nearly as many girls as boys take advanced physics and math courses, but by the time they finish college, most of them have gone into other fields. Only about 9% of practicing engineers are women (WEPAN 2006).

In academia, supply-side analyses tell only part of the story, however. As Donna Nelson and others have demonstrated, in university hiring the pipeline is often under-used, especially at elite research universities. For example, although women earn over 20% of computer science doctorates, they are less than 11% of assistant professors in the "Top 50" computer science departments. At the higher ranks, where departmental decisions are made, the situation is even worse: barely 3% of full professors in engineering, computer science, and physical science are women. Minority women, only 2% of the science/ technology faculty nationally, are "virtually nonexistent in research universities" (Nelson 2005).

Women leave academic careers much more frequently than men do, taking jobs in business and industry where there is no tenure clock to create conflict with the biological clock and where family-friendly policies and resources make it somewhat easier to have a balanced life (Widnall 1988; Long 2001; Preston 2004). Those who stay in academia earn 2 to 5% less than their male peers for equal performance (Ginther 2004). They are tenured and promoted at slower rates than men (Sonnert & Holton 1996a; AAUP 1997; Ginther 2004; Perna 2005). They are a minority in every rank, regardless of discipline (Valian 1998; Nelson 2005). They are especially scarce among academic decision-makers (Perna 2005).

The "productivity puzzle" is sometimes evoked to explain this disparity: male faculty achieve greater success simply because they publish more papers on average than female faculty do. However, even if this assertion is true (and the evidence is mixed), it misses the point (Cole & Zuckerman 1984, Sonnert & Holton 1996a, Long 1992, Xie & Shauman 1999, Stack 2004). Given the unequal constraints and burdens on their lives--the complex logistics of the Second Shift (especially the care of preschool children); the toll of "token overload"; the stress of being

an outsider, hypervisible and invisible at once, negotiating a promotion and tenure system whose rules and processes are far from transparent; and, most of all, given the irremediable losses that occur when one is excluded from the informal, collaborative research/learning peer networks that constitute the circulatory system of the university---given all these extra weights to carry, what it is really "puzzling" is how extraordinarily productive women faculty are.

On average women faculty have a higher per-paper citation rate than their male peers (Zuckerman 1987; Sonnert 1995a; Long 1992). That is, they do better quality work. And, indeed, they have to! In their famous 1997 study of gender bias and nepotism in peer review, Wenneras and Wold demonstrate that "peer reviewers cannot judge scientific merit independent of gender." They conclude that "…a female applicant had to be 2.5 times more productive than the average male applicant to receive the same competence score as he…." That is, women in academia have to work harder than their male peers just to stay two steps behind them. Under the circumstances, "Why so few?" is the wrong question to ask.

And "leaky pipeline" is the wrong metaphor. Hydraulic interventions--e.g. pump-priming the flow at the source--are modestly effective but unlikely to produce sustainable systemic change because the pipeline imagery misrepresents the nature of the problem. Academic institutions do not contain women in the passive way that a pipe contains water. Universities are run by "invisible colleges" within them, composed of informally networked male peers. These networks are organic, dynamic, continually reproducing themselves in the very act of being. And women faculty are positioned outside the circle, especially in STEM fields. Scattered by ones and twos among disparate departments, they stand alone like silos on a Kansas wheat field. This isolation is devastating and circular. It creates negative feedback loops that are extremely difficult to interrupt. Few women want to go to places where few women are. And this is a sensible stance: gender schema bias increases exponentially as the proportion of women in a given population decreases (Valian 1998). Women know this intuitively. They count the house and stay away if they lack a quorum. In short, the best way to achieve critical mass is to already have critical mass.

Moreover, problems inherent in the very concept of "critical mass" make this conundrum even more daunting. Research suggests that the add-a-few-women-and-stir approach doesn't do much, without changing "the structure of the scientific workplace" (Etzkowitz, Kemelgor & Uzzi 2000). The usual definition of critical mass, 15%, is not a magic number. The women may be of different nationalities and may self-isolate. They may not even know each other. "Toxic" departmental culture may discourage female bonding. And yet at the same time, as Etzkowitz and others have observed, "modest increases in the number of women [do] bring about changes in departments." There are "higher levels of support and identity enhancement." "A critical mass of women promotes the development of a well balanced network of strong ties."

At issue here is the difference between what might be called numerical critical mass and functional critical mass. The former simply counts the number of women in the organizational container. The latter maps the structure of the connections among the women--and among them and their male peers. Functional critical mass changes more than the number. It changes the way men see women (dampens the gender schema effect); and it changes the way women see themselves (the quorum sensing effect). (See Boylan 2004.) Numerical critical mass generates

official claims of progress, claims that are often illusory. Functional critical mass generates strategic power for sustainable structural change.

To create functional critical mass, universities need to take a modular approach to the architecture of transformation. Just as "each-one-teach-one" methods can produce exponential dissemination of knowledge in a closed system, gender climate change can be grown locally and then exported to the academic institution as a whole. At NJIT, we believe that the best way to do this is to enable and seed-fund a network of small interdisciplinary research collaborations among current women faculty and a few of their male peers. By positioning these female-majority research communities in the interstices between disciplinary departments, university change agents can exploit what sociologist Mark Granovetter (1973, 1983) has called "the strength of weak ties" (Burt 1998). This strategy unfolds from an understanding of how informal collaborative networks generate social capital for male faculty.

Collaborative Networks and Social Capital Banking

At technological research universities such as NJIT, faculty members achieve success by maximizing their store of Scientific and Technical Human Capital, defined as "the sum of a researcher's professional network ties and their technical skills and resources" (Bozeman & Corley 2004). The formula is simple: Human Capital + Social Capital = Promotion and Tenure Outcome. On the surface at least, it is relatively clear what these terms mean. Human capital is "What You Know"; Social capital is "Who You Know" (Etzkowitz, Kemelgor & Uzzi 2000). "Social networks have value," Robert Putnam reminds us in *Bowling Alone* (2000). "[They] affect the productivity of individuals and groups." However, not all networks have equal value. In order to generate social capital, "norms of reciprocity and trustworthiness" must develop among "contacts." People invest in social networks in order to gain access to other forms of capital, but not all of those investments pay off (Perna 2005).

Ronald Burt, building on Mark Granovetter's pioneering work on "the strength of weak ties" (1973, 1983), has developed the concept of "structural holes" to describe the "information and control advantages of being a broker in relations between people otherwise disconnected in the social structure" (Burt 1998). Entrepreneurial managers intuitively position themselves at the crossroads within organizations, bridging otherwise isolated subunits. Having privileged access to information within each unit, the manager bridges the gap, accruing social capital by managing the flow of information between the units. [The literal meaning of entrepreneur is "a person who adds value by standing in between" (Burt 1998)]. Acquiring "strong ties to a large array of disconnected groups, within and outside the organization," the entrepreneurial manager makes himself attractive, which, in turn, generates more opportunity for "bridging ties" (Burt 1998; Granovetter 1983). Such networks, rich in structural holes and hence rich in social capital, lead to early promotion for the manager--and to advancement for his entire team (Burt 1998).

In academia, male faculty members use a similar approach to achieve tenure and promotion, especially in scientific and technological disciplines where collaborative research projects and multi-authored papers are the norm. In *Athena Unbound* (2000), Etzkowitz, Kemelgor and Uzzi wryly compare male faculty networks to Melanesian Kula Rings:

…elite scientists who are linked by ongoing networks of relations and governed by norms of trust and reciprocity ritualistically meet to discuss collaborations, discover complimentary areas of research, and introduce their graduate students and post-doctoral fellows to each other for future correspondence and employment.

Male protégés are introduced into these networks by their mentors in graduate school, with whom they serve a cognitive apprenticeship. They draw on the senior faculty member's bank of social capital initially, until they have accumulated enough to open their own accounts. Although graduate school is ostensibly a meritocracy powered by a strong individualistic ethos (The Lone Scientist), for male graduate students it functions more like a coterie, protecting and nurturing their development. Success generates positive feedback from the network which, in turn, generates more success (the "halo effect": Etzkowitz, Kemelgor & Uzzi 2000). This same process tends to continue when male graduate students become young faculty members (Etzkowitz, Kemelgor & Uzzi 2000). The networks they are helped to build form conduits through which S&T capital flows to them in many forms: access to tacit knowledge; access to new and novel information; advanced notice of jobs postings; news about hot research areas and funding opportunities; access to unpublished research; invitations to join grant initiatives; the opportunity to vet their work and reality check their views; support for intellectual exploration and risk-taking; guidance that demystifies the PROMOTION AND TENURE processes; and, not least, brokered connection to the high status people who will eventually judge their worth. It is this "Friendship Bonus" that Wenneras and Wold measured in their 1997 study of nepotism in peer review--a bonus that male faculty members are eligible for, by virtue of their gender. And for which women faculty are not eligible, by virtue of theirs.

The Consequences of Isolation
The exclusion of women from informal faculty networks is not generally a conspiratorial process, nor even a conscious one. It is so hard-wired into the system that it is essentially invisible. Just as the high-level success of a few super-performing women "role models" tends to obscure the ways in which women as a group are being disadvantaged, instances of successful collaboration between women and men tend to obscure the cumulative damage that isolation does to many women's careers (Etzkowitz, Kemelgor & Uzzi 2000). At NJIT as elsewhere, men and women do form collaborative partnerships, some of them quite enduring; but they tend to be insular, dyadic arrangements within a home department. It is much more difficult for women to adopt the entrepreneurial style described by Burt in which one accumulates bridging ties to a large array of disconnected groups.

Moreover, even when women adopt such a style, it tends to work against their advancement, rather than for it (Burt 1998). The reasons for this paradox are complex, the most important being women's status as Outsiders in the scientific/technological enterprise. Burt (1998) wryly uses the Yiddish term *mishpokhe* ("one of us") to describe how binary thinking (us/them) generates stigmatization. In the professions generally and at institutes of technology in particular, women are "NOT- *mishpokhe*." They are suspect by default. Since the formation of social networks requires a mutual belief in one's partner's "trustworthiness," even women who form many "weak ties" are less likely than their male peers to elicit the reciprocity from those ties required for social capital formation. And low social capital correlates strongly with lack of career success (Putnam 2000).

In science and technology, women are Outsiders in part simply because there are so few of them. If women were "right for the job," there would be more of them around, men reason, as do many women as well (Valian 1998). Minority status carries with it an intrinsic scent of failure, and deviance. Thus lack of "critical mass" tends to generate a negative feedback loop, making it more and more difficult to achieve critical mass.

Although unequal responsibility for childcare is the most frequently discussed extra burden that women faculty bear (Long 1990, 1992; Xie & Shauman 1996; Etzkowitz, Kemelgor & Uzzi 2000; Bozeman & Lee 2003; Stack 2004)--the impact of Outsider status on women's careers is equally devastating. The process of exclusion begins in graduate school where women are often left alone to "pursue the myth of scientific individualism even as men…operate within networks of collaborative learning that advance most ideas competitively" (Etzkowitz, Kemelgor & Uzzi 2000). Isolation and consequent spotlighting increase the pressure to super-perform while at the same setting up the conditions for failure (Etzkowitz, Kemelgor & Uzzi 2000; Steele 1997). Many women are socialized to expect to get less and to reward themselves less (Sonnert & Holton 1996; Valian 1998; Babcock& Laschever 2003). Isolation limits opportunities to reality-check these expectations and evaluations and to get vetting for new ideas and research initiatives. It limits access to tacit knowledge; news about hot research areas and funding opportunities; access to unpublished research; invitations to join grant initiatives; support for intellectual exploration and risk-taking; guidance that demystifies the PROMOTION AND TENURE processes; and, not least, brokered connection to the high status people---in short, it cuts women off from all of the assets that flow to male peers through their social networks (Creamer 1998; Etzkowitz, Kemelgor & Uzzi 2000).

Women are socialized to be sociable and to enjoy collaborative work (Etzkowitz, Kemelgor & Uzzi 2000; Pfirman 2004). Yet women faculty in science and technology are somewhat more likely than their males peers to work alone (Mitchell 1999). And likely to have fewer partners even when they do collaborate (Cole & Zuckerman 1984; Fox 1991; Bozeman & Corley 2004). Nor do they collaborate with other women as frequently as one might expect (Bozeman & Corley 2004). At ethnically diverse institutions such as NJIT, differences in cross cultural gender schema and culturally-driven communication norms create additional constraints. Since "cosmopolitanism" in collaboration (i.e., number of collaborators) is positively associated with productivity and increased S&T Capital, isolated women researchers often find themselves on a treadmill to oblivion (Crane 1975; Bozeman & Lee 2004; Perna 2005; Lee, Wong, & Chong 2005).

Etzkowitz, Kemelgor and Uzzi (2000) theorize that women faculty instinctively (or consciously) work harder to accumulate greater human capital in order to compensate for lack of social network capital. However, this strategy often backfires, amplifying the tendency toward perfectionism and risk-avoidance that is still part of female gender socialization (Valian 1998). Lacking positive feedback from mentors and peers, women sometimes feel that they have to know everything before they can say anything, whereas their male peers believe that if they know 20% of something, they can "bullshit the rest" (Etzowitz, Kemelgor, Neuschatz & Uzzi 2000). The career consequences of the "80%-20% Rule" are illustrated with stark clarity in Mick Jackson's 1987 film *The Race for the Double Helix*, starring Juliet Stevenson as Rosalind Franklin. The film's montage structure connects the careful, linear, exhaustive (and exhausting)

way in which Franklin tries to decode the structure of DNA with her absolute isolation in the social structure of King's College--and contrasts that isolation with the rich web of social/professional connections that Crick and Watson are able to exploit as they network themselves to the Nobel Prize.

A Strategy for Change
The Double Helix depicts Franklin in frustrated rage calling on Crick and Watson to stop their "little boy games." Similarly, gender equity projects in the past have often called for an end to the "old boy's network" in academia and a return to strict meritocracy. This approach is inherently problematic, however. Even in elementary school classrooms where an excellent paper (almost) always gets an A, meritocracy is largely an illusion; and in universities and other large organizations, it is an impossibility. Fair-reward-for-effort requires ongoing negotiation from a position of strategic social strength, and networking is an essential part of that process.

Gender schema bias tilts the playing field even further. As Virginia Valian argues persuasively in *Why So Slow?* (1998), professional competence is gender-schemic for men but gender-aschemic for women ("out of role'). "Their most important consequence for professional life is that men are consistently overrated, while women are underrated. Whatever emphasizes a man's gender gives him a small advantage, a plus mark. Whatever accentuates a woman's gender results in a small loss for her, a minus mark." (See also Steinpreis 1999). Gender schema bias in evaluation is amplified when women are few in number and isolated. "The fewer the women the more they will be evaluated through the lens of gender norms and expectations," Valian (1998) notes.: "…Being in a minority increases a woman likelihood of being judged in terms of her difference from the male majority, rather than in terms of her actual performance." "Women are at risk in settings where they are less than one-third of job occupants" (Valian 1998) [This] "can explain some of the difficulty women have entering [and advancing in] heavily male-dominated professions," she adds in something of an understatement.

 "Be where women are well-represented," Valian counsels her readers. As first glance, this advice seems to offer little hope, especially for women in physical science and technology; but in fact, it offers a methodology for change. It is true that the fewer the number of women, the more powerful gender schemas become. However, the reverse is true as well. There is an enormous body of research demonstrating that the way in which men and women behave, think, and evaluate each other changes dramatically as gender ratios change within the group. The more numerous women are, the less power gender schemas have. "If a woman is one of many, she is less likely to be perceived in terms of her sex and her job is less likely to be perceived as a man's job" (Valian 1998; see also Heilman 1980; Sackett, Dubois, & Noe 1991; Aries 1997). The tipping point seems to be >30% ((Etzkowitz, Kemelgor & Uzzi 2000).

Given the current glacial pace of change, it may take decades (possibly centuries!) before the faculties at US technological universities reach 30%; and even then, as I suggested earlier, the silo-like disconnection of academic departments may prevent the formation of functional critical mass within the university as a whole. In response to this conundrum, at NJIT we propose to achieve macro-level change in the long run by focusing on micro-level interventions in the short-run. Specifically, we propose to support the creation of small interdisciplinary communities within which women faculty can do collaborative research with each other and select male peers

from a position of numerical strength. This strategy builds on Sue Rosser's observation that women researchers often respond to a "chilly" university climate by creating "a small, empowering environment in their own labs, within a larger, hostile environment" (Rosser 2004).

Using both traditional networking techniques and new pervasive information technology (P3 tools), we will then foster bridging ties among these small female-majority research communities, and link them to administrative change agents in a Keiretsu structure--i.e., a loose circle of independent entities that have stake in each other. That is, rather than trying to dismantle existing male faculty alliances, we propose to create mirror-image emulations of them. Instead of plugging the holes in the "leaky pipeline," we propose to build on top of the holes in the organization chart--positioning nodes of women researchers and a few male peers in the interstices between departments and the connecting those nodes laterally and vertically into an entrepreneurial network through which privileged information will flow. Like making "stone soup," this strategy will transform nothing into something--an empty space into a strategic asset.

We hypothesize that mobile wireless location-aware computer networks can be used to support such collaborative research networks. We propose to test this hypothesis using NJIT's new NSF-supported SmartCampus location-aware community system test-bed, which will locate users on campus, typically within a few feet, and deploy a variety of systems that link People-to-People-to-geographical-Places---"P3-Systems" (Jones 2004). Ideally, these systems will strengthen the emerging community of women researchers at NJIT by helping individuals leverage location information to: 1) meet appropriate people and turn acquaintances into friends and collaborators; and 2) better coordinate the interactions with colleagues around project work. We will study such questions as to whether women faculty have different P3 tool preferences or privacy issues than male faculty. Gaining a better understanding of the relationship between individual attributes, location/place, social networks, and GeoTemporal data-sharing preferences will help NJIT and other universities learn how to better support collaborative research teams. We plan to use a variety of research methods to explore these issues, including semi-structured interviews, focus groups, user surveys and longitudinal monitoring of who-to-whom network traffic to identify changes in social networks. Since the SmartCampus software will be made available in the public domain after the completion of the research projects, what NJIT learns from this research can be used to help build and support collaborative research networks among women on other campuses.

In addition to using new pervasive information technologies to interconnect small, women-centered "collaboratories," we also plan to increase social capital of women faculty members by establishing linkages between women in academia and mentors in business and industry. In the first phase of this process, already underway, NJIT provost Dr Priscilla Nelson has established an External Diversity Advisory Board, composed of a mix of high-status women and men who have a demonstrated commitment to the advancement of women and minorities in science and technology. The Advisory Board will partner with the provost and others to host ongoing meetings and retreats with the deans and departmental chairs. At these sessions, Board members will share industry best practices in training, evaluation, advancement, and work-life balance--lending an extra measure of peer pressure to the effort to legitimate new cultural norms. Principal among these new norms is a shift from an adversarial departmental stance toward PROMOTION AND TENURE ("weed 'em out") to the advocacy approach more common in business in which

managers have accountability for the success of their new hires and are expected to coach them. Diversity Advisory Board members will also help the provost identify external resources that can be leveraged to support the new women-majority micro-communities.

We plan to increase this load-bearing surface still further by matching individual women faculty with senior women in business and industry in their research fields. The women in industry will function as mentors to their faculty partners, increasing access to information about industry research agendas and, where feasible, offering summer research "internships." In turn, the university will provide women in industry with opportunities to work periodically in academia as "professors of practice." We believe that, in turn, these partnerships will stimulate new synergistic research activity, increasing the social capital of women faculty researchers. Enlarging the audience in this manner, will also create leverage in the departmental PROMOTION AND TENURE process, helping to identify and vet potential women leaders and advance their careers.

A New Assessment Strategy

Because institutional culture is organic and dynamic, traditional head-count methods of measuring progress toward gender equity are inadequate. Hence, we propose another assessment strategy, one that is consonant with the concept of "functional critical mass": mapping networks in research-oriented social space over time.

Like most universities, NJIT tracks a standard set of variables, including 1) Faculty recruitment patterns; 2) Women's representation in senior administration; 3) Women's research productivity; 4) Women's access to research materials and space; 5) Access to and use of family support programs. In addition, however, we now propose to conduct a detailed study of cultural practice based on data about faculty contact and collaboration. The tracked computer contacts from our pervasive information technologies experiment (above) will give us the opportunity to measure contact among diverse individuals. Twice a year, we will use this and other data to survey academic contacts and research reciprocity among faculty. This will allow us to the map the university's social space and create a graphic representation of changing social networks.

We believe that, over time, the collaborative networking strategies I have outlined in this paper will move women faculty toward increasingly important positions within university research. The relative importance of their role will be measured in the variety and frequency of research-oriented contacts. We believe that not only will absolute research dollars increase, but the reciprocal contacts between women faculty and more active male research faculty will also increase. By mapping networks in research oriented social space over time, we will be able to assess with some precision the effectiveness of our efforts. If we are successful, both our fundamental strategy--diminishing the isolation of women faculty by creating hospitable micro-climates within the more problematic organizational climate as whole--and our dynamic assessment methodology can be replicated at other universities across the country.

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