

N is for Network: New Tools for Mapping Organizational Change

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Abstract: *Understanding network dynamics is important for underrepresented minorities and women in technological organizations, who can easily spend their entire careers on the periphery, far away from the flow of information at the core. We explore this problem by describing the results of a new study of faculty research networks conducted by the NSF-funded ADVANCE program at the New Jersey Institute of Technology (NJIT). Using tools such as ORA to analyze a database that contains nearly a decade of information about NJIT faculty publications, ADVANCE researchers have created dynamic co-authorship maps that provide an aerial view of the organizational landscape as it changes over time. By giving faculty and administrators guided access to such maps, university change agents can promote mentoring policies and practices that support the advancement of women and minority faculty.*

“To know who we are, we must understand how we are connected,” write Christakis and Fowler in their 2009 book on the power of social networks (xiii). This observation is true of organizations as well as individuals. Universities and corporations are not merely buildings and balance sheets; they are relational entities—webs of interaction and perception whose complex structure is largely invisible to the people embedded in them (O’Reilly 1991). Organizational networks are transformational engines (Ibarra, Kilduff, and Tsai 2005). They supply the social capital that powers career success, allowing young professionals to convert their human capital into status. Network structure drives institutional change as well, facilitating (or retarding) innovation—maintaining (or altering) norms, including norms of gender and race. Understanding network dynamics is especially important for underrepresented minorities and women in technological organizations, who can easily spend their entire careers on the periphery, far away from the flow of information at the core. As Christakis and Fowler note, “Network inequality creates and reinforces inequality of opportunity” (301).

The National Science Foundation (NSF) implicitly adopted a network perspective when in 2001 it created the ADVANCE Program as successor to the Professional Opportunities For Women in Research and Education (POWRE) program, shifting its focus from individual empowerment to institutional transformation. As Virginia Valian (1998) and other theorists remind us, such transformation requires more than a linear add-women-and-stir approach (Etzkowitz, Kemelgor & Uzzi 2000). It requires a three-dimensional understanding of organizational structure. In 2006, NJIT ADVANCE began a three-year proof-of-concept project designed to acquire such understanding and use it to create positional advantages for NJIT women faculty researchers, diminishing their potential isolation and increasing their access to novel information. In this paper, we provide an overview of our methodology and discuss the implications of the data we have acquired.

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Strategies: In formulating our original NSF proposal, we observed that the absence of women faculty in science and technology creates a negative feedback loop that resists change because few women want to go to places where few women are. This aversion is sensible since gender schema bias increases as the proportion of women in a given population decreases (Valian 1998). Women scientists frequently respond to such bias (the chilly climate) by creating “a small, empowering environment in their own labs” (Rosser 2004). Such micro-climates foster support, as do many of the women-to-women mentoring initiatives developed by Women in Engineering ProActive Network (WEPAN) and ADVANCE programs across the country. In network terms, however, same-sex ties (homophily) do not always work as well for female scientists and engineers as they do for their male counterparts. In organizations where men have long been dominant, there are strong incentives for men to seek instrumental ties to other men because men generally have greater status and access to resources than their female counterparts (Ibarra 1992, McPherson 2001). This status advantage is attributable to gender schema bias—the male competency bonus—(Valian 1998) and to the ongoing self-replication of male networks typified by a rich-get-richer phenomenon in which more male homophily makes more male homophily. In contrast, women are often forced to divide their energies—and divide their psyches as well—seeking support ties to other women but pursuing heterophilous ties to high status, well-connected men in order to realize their instrumental goals. Moreover, female desire for heterophilous ties may not be reciprocated. “If network contacts are chosen according to similarity and/or status considerations, [women] are less desirable choices for men on both accounts” (Ibarra 1992). In other words, the network strategies women adopt tend to be more costly and less effective than the strategies men adopt.

Hypotheses: Over the last three years, ADVANCE has studied patterns of gender homophily in NJIT faculty research networks even as we have worked to diminish homophily and to provide incentives for research collaboration among women and men from different disciplines. In designing our study, we made a number of assumptions about the status of NJIT women faculty, based on our reading of literature in the field and on quantitative and qualitative research we had conducted previously for the 2005 NJIT *Status of Women Faculty Report*. In particular, we posited that NJIT women faculty members are more isolated than their male peers, less likely to be in the information loop, and less likely to be tied to high-status, well-connected colleagues. Being out of the loop makes it harder for women to accumulate social capital which, in turn, has a devastating effect on retention and advancement, we observed, especially in the science, technology, engineering, and mathematics (STEM) disciplines where collaborative research projects and multi-authored papers are the norm. Isolation limits women’s opportunities to reality-check their expectations. It limits access to tacit knowledge. It blocks the flow of 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 opaque promotion and tenure processes, and, not least, brokered connection to the high status people. In short, it cuts women off from all the assets that flow to male peers through their social networks (Steffen-Fluhr 2006). We theorized that NJIT male faculty members are less likely to collaborate with female faculty than with their male colleagues and that this collegial asymmetry is likely to result in reduced productivity for the women, as measured by number of publications. In general, we hypothesized that increased collaboration is positively associated with career success, as measured by acquisition of tenure and promotion up the ranks—especially cosmopolitan collaboration across disciplines.

Methodology: As in medicine, where treatment is sometimes begun even before the lab results have arrived to confirm the diagnosis, in 2006 NJIT ADVANCE initiated programs designed to stimulate interdisciplinary cross-gender research collaboration even before we had verified our hypothesis that collaboration is positively correlated with career advancement for women. This decision was fortunate, since it proved extremely difficult to collect the faculty network data required for our study. In year one of our project, we concentrated primarily on self-reported data gleaned from a friends and colleagues survey instrument initially administered in one-on-one interviews and in small groups. We also developed a sense of community survey that measured departmental climate and campus-level climate on an 11-point scale. Unfortunately, when we fielded the network survey online, we decided to combine it with the climate survey, creating an instrument that was too long for the attention spans of many of our male faculty. Nearly 80% of the women faculty completed the social network survey, and we had additional data from our pre-test sample; however, less than 20% of male faculty did so. Because our self-reported data were too small and too skewed to be useful for network analysis, we subsequently focused on collecting objective bibliometric data, hypothesizing that co-authorship linkages were a valid proxy for NJIT faculty network ties.

From 2006 through 2009, ADVANCE researchers designed, built, populated, and validated an interactive database of NJIT faculty publications using semi-automated affiliation searches to mine Scopus and other repositories for which the NJIT library has licenses. The database now contains 2208 author names and 7225 publications. Some of these publications go back decades, but we have concentrated on achieving a high-degree of accuracy for the period 2000-2008 because it gives us before and after snapshots we can use to gauge the impact of ADVANCE interventions. A user-friendly interface in the database allows faculty members to access and update their entries and to generate simple ego-maps of their research networks via HyperGraph. ADVANCE administrators can also use the database to generate co-author lists and answer basic statistical queries, disaggregating data by gender, department, and tenure status.

Though a satisfying achievement after so much labor and frustration, the successful construction of the database was always a means to an end. It gave ADVANCE researchers the ability to map the connections (and disconnections) among NJIT female and male faculty and analyze the significance of those network patterns for promotion and tenure. We began by defining the population we proposed to study. Of the 2000+ authors in our database, we chose 463 tenured/tenured-track STEM faculty members who had been employed full-time for all or part of the period 2000-2008. (We also included a small group on non-tenure-track Research Professors who are supported on soft money.) We approached the data in two somewhat different ways: 1) we performed statistical analyses on the whole-network data, testing various hypotheses about gender, collaboration, and advancement; and 2) we did case studies of selected male and female faculty ego-network maps, comparing and contrasting individual patterns of collaboration and career advancement as they developed over the nine-year period.

Hypothesis Testing: “The more paths that connect you to other people in your network, the more susceptible you are to what flows within it” (102), Christakis and Fowler observe. If you are at the center of a network, you are likely to have many more direct and indirect connections to other people than if you were at the periphery. “Consequently, you can earn a centrality premium if good things...are flowing through the network. More people are willing to act altruistically toward you than toward those at the margins” (Christakis and Fowler, 299). In academic networks, the good thing that flows through the network is information—including information about status and reputation. If women faculty members are less centrally located

than male faculty, they will incur greater information-foraging costs and have fewer opportunities to signal their value as organizational players, a difference that may constitute a structural constraint for advancement (Burt 1998). The authors of the 2009 National Academy of Sciences (NAS) report *Gender Differences at Critical Transitions in the Careers of Science, Engineering and Mathematics Faculty* express concern about this possibility when they observe that women faculty members in the NAS study “were less likely to engage in conversation with their colleagues on a wide range of professional topics, including research. This distance may prevent women from accessing important information and may make them feel less included and more marginalized in their professional lives.” The report concludes by calling for future research that will give us a deeper understanding of why “female faculty, compared to their male counterparts, appear to continue to experience some sense of isolation.” The NJIT ADVANCE network study responds directly to the NAS call, demonstrating that social network analysis (SNA) methods can be used effectively and efficiently by gender and technology researchers to measure relative network isolation and its impact on women’s careers.

To explore the relationship between network structure, collaboration, and career advancement, we tested a set of hypotheses using three SNA tools to analyze co-authorship data: 1) UCINET, a relatively inexpensive software program (developed by analysts Steve Borgatti, Martin Everret, and Lin Freeman and marketed by Analytic Technologies) that is used to measure various forms of network centrality and to perform statistical analyses; 2) ORA (Organizational Risk Analyzer), a powerful and relatively user-friendly freeware package developed at Carnegie Mellon; and 3) PNet, freeware for the simulation and estimation of exponential random graph (p^*) models, developed by a team of social network analysts at the University of Melbourne. Embedded in UCINET is a freeware visualization tool called NETDRAW. ORA may be used to generate sophisticated data maps as well.

Hypothesis 1. Women are more likely to be peripheral agents in the network, thereby having a lower centrality (degree centrality, Eigenvector centrality, and betweenness centrality) than their male peers. Centrality comes in a number of different flavors, each of which constitutes a distinct network advantage. *Degree centrality* helps to identify well-connected people who can directly reach many other people in the network. Being well-connected means that a person has easier access to more sources of information and is exposed to more novel ideas, all of which are important for academic advancement (Ibarra et al. 2005, Whittington and Smith-Doerr 2008; Gonzalez-Brambila, Veloso, and Krackhardt 2008). However, having many connections does not always constitute power. A person can be central within her group of close friends, but if nobody in that group is connected to a larger network, then even the central person can find herself quite isolated. To account for such situations, we relied on another measure called *Eigenvector centrality*. In addition to counting the number of direct connections, this measure assigns higher weights to well-connected connections. In other words, Eigenvector centrality looks for the importance of one’s connections, not simply their number. People with high Eigenvector centrality are able to reach other people in the network quickly if the need arises. The third measure we used in our testing is *betweenness centrality*. This measure reflects the extent to which a person has the ability to control information flow in the network. In general, betweenness counts how many times a person functions as a missing link between two people or groups who are not connected directly. Among other things, high betweenness may indicate an interdisciplinary research agenda.

Centrality Results: For the period 2000-2008, the mean values for all three centrality measures were consistently higher for male faculty than for female faculty. This suggests that

male faculty tend to be more central in the network than female faculty. For the period 2000-2005, the mean difference in Eigenvector values of 3.25 between male and female faculty at NJIT was statistically significant based on t-test ($p = 0.05$). This confirms that, before NJIT ADVANCE, female faculty members were less likely than their male peers to be connected to well-connected individuals (the power players). In recent years, however—i.e. after NJIT ADVANCE began—the Eigenvector centrality of women faculty has increased relative to their male peers, an indicator that women are becoming more important players at NJIT.

Hypothesis 2. Male faculty are more likely to collaborate (co-author) with other male faculty than with women faculty. As we indicated above, in historically male-dominant environments (e.g. engineering schools!), our natural human tendency to seek ties with people we perceive to be like ourselves (homophily) can have subtle but devastating effects on female faculty advancement. Homophily drives network centrality in a loop. In this closed social space, parity is not enough: a favorable network position does not create as much leverage for women as it does for men (Ibarra 1992). Nor does a favorable position on the organization chart. Indeed, women may need much higher Eigenvector values than their male peers in order to establish baseline legitimacy (Burt, 1998). It is especially important for WEPAN and ADVANCE programs to be aware of these issues as we design support structures for women faculty, lest we inadvertently make a bad situation worse. In developing our own program initiatives, NJIT ADVANCE has worked consistently and effectively to broker heterophilous ties among faculty across disciplines and sectors, in the belief that minority groups especially benefit from cosmopolitan networks (Ibarra et al. 2005, Rhoten and Pfirman 2007).

Method and Results: In order to establish a metric for changes in organizational homophily, we used a statistical modeling approach. We counted the absolute number of ties within and between male and female faculty groups. (All isolated nodes were removed from the network prior to the analysis.) To interpret these numbers, we used Krackhardt and Stern's (1988) E-I index which measures group embedding on a scale from -1 (all ties are within the group) to +1 (all ties are with external members of the group). For our data, the E-I index was equal to -0.64 suggesting that most of the ties in the network are between members of the same group. To make sure that the results are not influenced by chance alone and/or by the large number of male faculty in the data set, we also used the Joint-Count test (also known as *categorical autocorrelation*) available in UCINET. The Joint-Count test measures the density of ties within and between the two groups and then compares these values with values from thousands of randomly generated networks with the same number of female and male faculty members but without the assumption of homophily. Based on 10,000 random permutations, the average number of cross-group ties that exists in a random network was 93.7. However, we actually observed 71 cross-group ties in our network. The difference is 22.7 fewer cross-group ties than what one would normally expect by chance alone, and this difference is statistically significant based on this test ($p = 0.03$). This means that cross-gender ties are significantly less likely to appear in our observed network than in a random network. Our initial hypothesis is thus confirmed for the entire period under study. That is, from 2000 through 2008, male faculty members were much less likely to collaborate with female faculty than with their male peers. This finding seems to confirm the assumptions made in our original ADVANCE proposal and, in combination with the results of hypothesis 1, begins to illustrate what the 2005 NJIT *Status of Women Faculty Report* tactfully termed “asymmetric collegial interaction.”

Hypothesis 3. Network centrality predicts faculty retention better than number of publications. Since network centrality and publication rate are different things, we decided to

test these measures separately in relation to retention. In terms of centrality, a person does not necessarily have to publish a lot to be important. She can acquire a high centrality value merely by co-authoring with well-connected individuals. Conversely, a person with a high number of publications can still be isolated in our data (with centrality equal to 0), because he or she did not co-author with any other faculty member at NJIT. To ensure accuracy, we thus began by removing 69 potential outliers from the data. We normalized centrality measures and the number of publications for each of the remaining 394 people by the number of years they were present in our data set. We then separated the population by gender —335 men and 76 women—and tested each group separately using a t-test for network data available in UCINET. The results show that for the men, publication rate was a significant indicator of their likelihood of leaving or staying at NJIT ($p = 0.03$). That is, a male faculty who published more per year was more likely to stay at NJIT than somebody who was less productive. However, for the women, Eigenvector centrality seems to have been the leading indicator of retention. Specifically, the difference of 0.2 in means of the normalized Eigenvector centrality between women who stayed at NJIT versus those who left was statistically significant ($p = 0.02$). In other words, a male faculty member at NJIT is more likely to stay if he publishes a lot, but a female faculty member is more likely to be retained if she is connected to well-connected colleagues. Surprisingly, the number of publications was not a statistically significant factor for predicting retention for women.

Significance of Findings: The statistically significant correlation between network centrality and female faculty retention discussed above is extremely important for organizations such as WEPAN, NAMEPA, and ADVANCE since it means that we have now the ability to picture (visualize) career landscapes in meaningful ways—and the ability to predict, in real time, who will advance in academia and who is in danger of dropping out. We can use this new knowledge to create leverage for change in mentoring policy and practice. The 2009 NAS *Gender Differences* report notes that, “In every field, women were underrepresented among candidates for tenure relative to the number of women assistant professors.” The report calls for future research that will illuminate “the causes for the attrition of women... prior to tenure decisions” and urges universities to address “the retention of women faculty in the early stages of their academy careers.” The work done by NJIT ADVANCE on network mapping and retention responds to this call, creating a potential new best practice in the mentoring of junior faculty.

Network Centrality, Productivity, and Innovation: In a ground-breaking 2008 study, Gonzalez-Brambila, Veloso, and Krackhardt examined the relationship between network structure and academic productivity using a large faculty co-author database. They concluded that faculty researchers publish more and publish higher quality work (as measured by citation counts) when they have a high number of direct network ties (degree centrality), are part of a sparse network, are central in the network (as measured by Eigenvector), and collaborate with researchers in other disciplines. This study supports the work of Ibarra (1993, 2005) and others who have long argued that there is a positive correlation between network centrality and innovation. Research of this nature has guided NJIT ADVANCE in our efforts to function as an institutional matchmaker, incentivizing the formation of interdisciplinary research ties among men and women faculty. More recently, we have been able to use our co-author database to test the validity of our assumptions about the beneficial effects of collaboration.

Hypothesis 4. During the period 2000-2008, NJIT faculty members who co-authored more with other NJIT faculty members had a higher average per capita publication rate than NJIT faculty members who co-authored less with other NJIT faculty members. This hypothesis was confirmed, below, as was a similar hypothesis about the publication rates of NJIT

engineering faculty. Initially, we planned to test this hypothesis by measuring and comparing the differences in the number of publications between the two faculty groups: those who co-authored with other faculty members at NJIT and those who did not. However, we realized that using binary criteria might well skew the results because faculty members who co-authored with just one other person would be grouped with faculty who co-authored with many people. Additionally, using binary criteria would make it difficult to test whether the number of collaborators had any effect on productivity (the number of publications). To address these concerns, we decided to use UCINET to conduct a regression analysis between the number of collaborators (measured as normalized degree centrality) and the number of publications to determine if there were any dependencies between these two variables.

The regression analysis found that there is a statistically significant, positive dependency between the number of NJIT co-authors and the number of publications (regression coefficient = 0.83; $p < 0.00$).^{*} Specifically, we found that 69% ($R^2=0.69$) of the total variance in the number of publications can be explained by variation in the number of co-authors. People who co-authored more at NJIT were more productive than those who co-authored less. To establish that the correlation between collaboration and publication rate held true across gender, we tested Hypothesis 4 separately for male faculty and female faculty. In each case, the hypothesis was confirmed. That is, for women, as for men, those who co-authored more published more. Even more important for WEPAN goals is our recent research confirming that there is a positive correlation between collaboration (network ties to co-authors) and increase in professorial rank. For the assistant professors, this correlation implicitly measured retention. (See below.)

Hypothesis 5. During the period 2000-2008, NJIT assistant and associate professors who co-authored more with other NJIT faculty members exhibited greater upward movement in rank than assistant and associate professors who co-authored less with other NJIT faculty. Based on t-tests for network data available in UCINET, the difference in means between the two groups (those who were promoted in rank and those who were not) was statistically significant (0.04; $p < 0.00$), as were the results when we ran the test again after removing 23 members who left NJIT in the studied period. (Both tests were run using the default of 10,000 random permutations.)

Women Faculty and Information Access - Case Studies: Because there are many other variables involved, it is impossible to know for certain whether the positive network changes for women faculty as a group described above (e.g., increased Eigenvector centrality) are the direct result of the NJIT ADVANCE project. To get at a more subtle qualitative assessment data that is sometimes obscured by statistical modeling, we did a series of case studies as well, comparing changes in the ego networks of selected female ADVANCE participants and their male peers from 2000-2008. To evaluate the correlation between network structure and faculty retention, we paid special attention to the networks of faculty members who left the university during the study period for reasons other than death or retirement. We illustrate this approach with several examples below. These case studies are not only instructive per se; they also demonstrate the revelatory power of data visualization (network maps).

Case A: Several women faculty who were actively involved in NJIT ADVANCE have risen to leadership positions during the last three years. Changes in the structure of their networks during this period correlate strongly with this advancement and, in a sense, predict it. For example, the sequence of map snapshots below clearly illustrates the growth of one emerging woman leader's co-authorship network and her increasing centrality in this network

(see Figure 1). (In the network visualizations, link or line colors represent different years of co-authorship.)

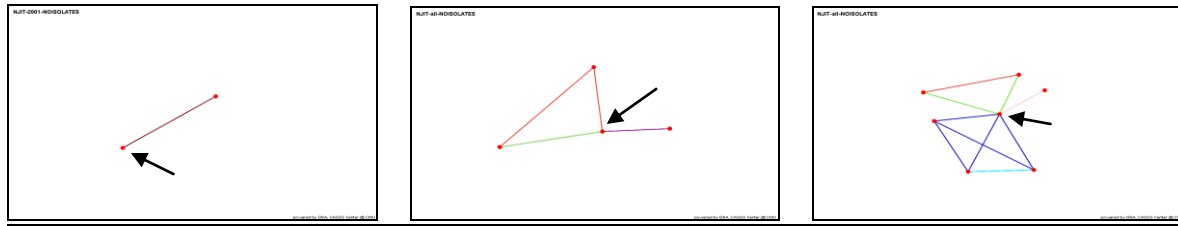


Figure 1. Changes in Eigenvector Centrality

The real power of this increased interconnectivity is even more apparent when we take the network out to three degrees (a collaborator’s collaborator’s collaborator), the apparent outer limit of network influence (Christakis and Fowler 2009). At three degrees, the network above right looks like this:

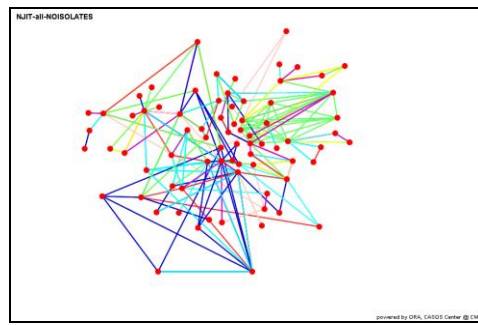


Figure 2. Network Complexity at Three Degrees

Using ORA or other visualization tools, we can rearrange the same map to illustrate more clearly the subject’s relatively high Betweenness value (right) as demonstrated by the size of her node in the network visualization (see Figure 3).

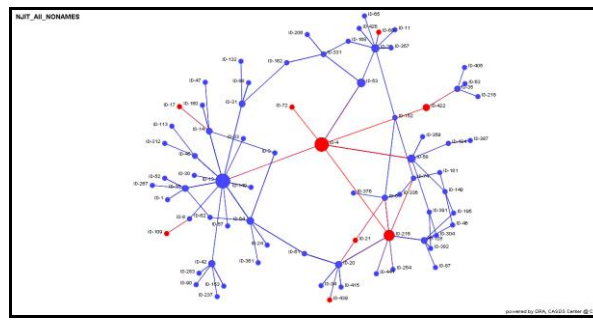


Figure 3. Betweenness Centrality

Case B: Most women faculty involved in NJIT ADVANCE activities exhibited network growth, but for some this increased connectivity may be fragile and temporary. As Christakis and Fowler note, “Loneliness is both a cause and a consequence of becoming disconnected” (57). In the following sequence, a faculty member who has long worked in relative isolation establishes

increased connectivity through ADVANCE, but most of this network complexity comes from a single new tie which, if severed, will lead once again to relative isolation.

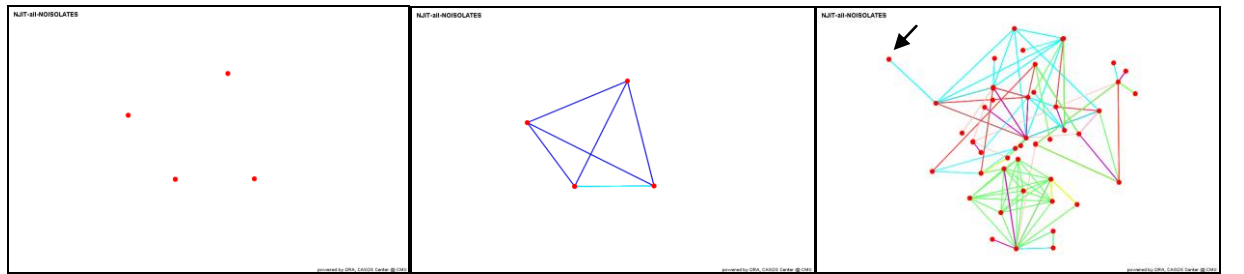


Figure 4. Fragility of Increased Network Centrality

Case C: In our network study, the faculty members who have the highest Eigenvector centrality values also tend to have the highest professorial rank (Distinguished Professor).[†] This is one of many indicators that encourage us to believe that our co-authors network is a good proxy for the NJIT faculty status networks—a hypothesis that we plan to test in future research. Evidence that network centrality is positively correlated with career advancement comes from the other end of the spectrum as well—that is, from case studies of faculty members who have not advanced or not been retained. The NJIT data we have collected fits all too well with the asymmetrical tenure/retention data reported in the 2009 NAS national study in which the number of female assistant professors coming up for tenure was far smaller than the number of male assistant professors. For example, at NJIT during the period 2000 to 2008, 124 male tenured/tenure-track faculty left the university's employ. The vast majority of these departures were senior faculty who either died or retired. Only 23 (18.5%) of the 124 were assistant professors who left without achieving tenure. During the same period, the numbers for the women tell a very different story. Of the 14 women who were not retained, six (42.8%) were assistant professors who left without achieving tenure. And another six (42.8%) were tenured professors who left because (to make a series of long stories short) they were unhappy.

Here again, network patterns tend to have predictive power. For the women at least, there is a strong correlation between being an isolate and leaving. This is not simply a question of publish or perish. Many of these women published as much as their male peers. It is the difference in network centrality that is salient. For example, compare the network structures in Figure 5 below. The faculty members in question came to the university at the same time. Both are prolific researchers who achieved tenure and senior rank. There is only one major difference: the faculty member represented by the network on the left (a woman) is no longer at the university.

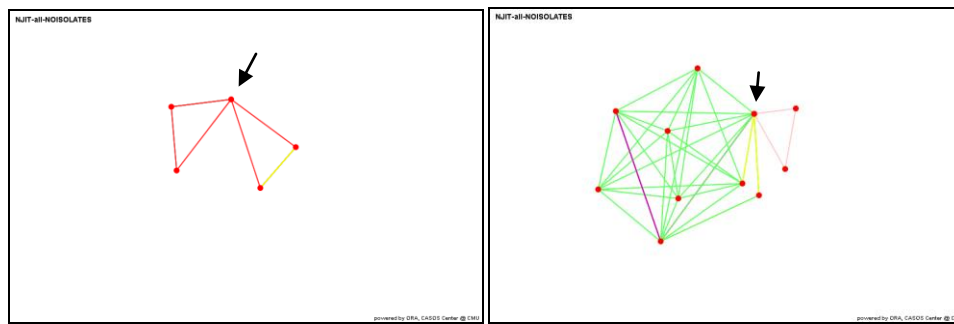


Figure 5. Network Structure and Faculty Retention

Implications of this Study for WEPAN and NAMEPA: Social scientists have long recognized the power of SNA to provide thick descriptions of organizational behavior, the kind of contextual knowledge that is a prerequisite for institutional transformation. In the past, it has been difficult for change agents to harness this power to advance underrepresented faculty, however, because collecting complete self-reported network data is problematic and laborious, even for experts. Garton, Haythornthwaite, and Wellman (1997) report that "one heroic researcher took a year to identify all the interactions in the networks of only two persons." As we discovered in our own research, it is notoriously difficult to get adequate response rates to surveys. Moreover, those who do respond are not necessarily always reliable (Dillman 1978.) Advances in data-mining, combined with the increased involvement of academic researchers in online social networks, offer a potential solution to this problem, allowing us to automate the collection of both bibliometric data (who co-authors with whom) and sociometric data (who talks to whom) —and to map the former onto the latter (White, Wellman, and Nazer 2004; Gruzd 2009, 2010; Gruzd and Haythornthwaite 2010).

To canalize the power of SNA on behalf of women and minority faculty, however, we need visualizations that will give us right-brained, immediate access to underlying network structure—pictures that will show what high Eigenvector centrality means, not merely give a numerical value for it. To achieve this goal, we are developing a new network mapping tool that will 1) give junior faculty access to the kind of satellite view of the organizational landscape that is normally attributed to senior faculty boundary spanners—a kind of GPS System for Career Management; 2) allow academic administrators to identify problematic characteristics of the units they manage; and 3) bring added value to the task of program assessment, allowing funding agencies to more accurately measure the effectiveness of the interventions they support.

As we have begun to demonstrate, bibliometric data—more and more easily accessible on a national/global scale—is a valid proxy for real-world faculty networks. Drawing on such data, in the future ADVANCE, WEPAN, and NAMEPA will be able to offer university policy makers new SNA tools to track changes in organizational health, to identify emerging leaders or isolated backwaters, or to compare the relative advancement of selected groups/individuals. In combination with traditional metrics such as the NSF 12, the ability to map changes in faculty networks over time provides a powerful holistic method of seeing institutional transformation as it unfolds.

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** The significance level was calculated based on a permutation test of 10,000 random trials to avoid the requirements of independence and random sampling that are not applicable to network data. In such calculations, it is not uncommon to see p-values less than 0.00.

† Of the 23 faculty members with the highest Eigenvector, 82% hold the rank of distinguished professor and 52% are recent winners of NJIT research or master teacher awards.