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Weaving the Native Web: Using Social Network Analysis to Demonstrate the Value of a Minority Career Development Program

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Abstract

Purpose—American Indian and Alaska Native scientists are consistently among the most underrepresented minority groups in health research. The authors used social network analysis (SNA) to evaluate the Native Investigator Development Program (NIDP), a career development program for junior Native researchers established as a collaboration between the University of Washington and the University of Colorado Denver.

Method—The study focused on 29 trainees and mentors who participated in the NIDP. Data were collected on manuscripts and grant proposals produced by participants from 1998 to 2007. Information on authorship of manuscripts and collaborations on grant applications was used to conduct social network analyses with 3 measures of centrality and 1 measure of network reach. Both visual and quantitative analyses were performed.

Results—Participants in the NIDP collaborated on 106 manuscripts and 83 grant applications. Although 3 highly connected individuals, with critical and central roles in the program, accounted for much of the richness of the network, both current core faculty and “graduates” of the program were heavily involved in collaborations on manuscripts and grants.

Conclusions—This study’s innovative application of SNA demonstrates that collaborative relationships can be an important outcome of career development programs for minority investigators, and that an analysis of these relationships can provide a more complete assessment of the value of such programs.

A 2003 report by the Institute of Medicine recommended that funding for investigator-initiated research should be increased and that training and educational strategies should be used to eliminate racial and ethnic disparities in healthcare.¹ Although the need to expand the pool of minority investigators is well-recognized, their representation among investigators funded by the National Institutes of Health (NIH) remains low.² This is unfortunate, because investigators from underrepresented groups are more likely than their

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majority-culture counterparts to focus on diseases and risk factors that disproportionately burden minority populations.^{3,4} Such investigators bring unique perspectives and experience that enhance our understanding of the factors underlying racial and ethnic variations in health and health status in the United States.⁵

Among the most underrepresented minority groups in health research are the Native populations of North America, specifically American Indians and Alaska Natives. Recent data estimate that fewer than a dozen Native scientists are principal investigators on R01 grants, with striking and continued underrepresentation at all funding levels and award types.²

Special initiatives, as exemplified by the National Institute on Aging's Resource Centers on Minority Aging Research, are enhancing the resources devoted to health issues of greatest concern to minority communities, including American Indians and Alaska Natives. Each Resource Center has several essential components, including an Investigator Training Core. The Native Elder Research Center, which is based in Seattle, Washington, and Denver, Colorado, includes an Investigator Training Core known as the Native Investigator Development Program.⁶ This program provides intensive mentoring of promising junior American Indian and Alaska Native investigators (hereafter "Native Investigators") in the social, behavioral, and health fields. Founded in 1998 and modeled on the highly successful Robert Wood Johnson Clinical Scholars Program,⁷ this program has 2 overarching, explicit, and mandated measures of the success of an investigator: publication and grant support.

Federally funded interdisciplinary and community-based research programs increasingly need to demonstrate success and capacity-building that exceed traditional academic standards. Yet American Indian and Alaska Native investigators who work with tribal communities often face unique challenges. As a result, conventional scholarly benchmarks may not adequately reflect their career trajectories and productivity. Further, such benchmarks often seem disconnected from the needs and interests of tribal communities.⁸⁻¹⁰ For example, research productivity may be associated with successful relationships and collaborative efforts, yet we have no way of evaluating how these factors contribute to success. Thus, academic medicine needs new tools that recognize the existence of networks of like-minded investigators who focus on common goals, in place of mechanisms that concentrate only on individual career paths. These new tools may create opportunities to transform research and training into products and practices that improve the health of tribal people and reduce health disparities.

Social network analysis (SNA) is a well-studied approach that can describe how investigators function in networks of relationships.¹¹⁻¹⁵ SNA has been used to evaluate collaborative relationships in educational and research communities^{11-13,16,17} and to assess progress toward building transdisciplinary relationships among investigators.¹⁵ In the case of the Native Investigator Development Program, the network of faculty and trainees is called the Web of Indigenous and Native Researchers (WINR). SNA is uniquely suited to evaluating projects like WINR because measures of successful career development can include membership in networks of researchers committed to a common purpose. In the present study, we used SNA to map the formation of WINR's collaborative network and systematically summarize data that are typically recognized only informally, even though such information is highly valued by funders, researchers, trainees, and community leaders. Our goal in using SNA in this setting was to provide a more complete demonstration of the value of a minority investigator training program.

Method

Program overview

The Native Investigator Development Program, a collaboration between the University of Colorado Denver and the University of Washington, provides a training environment that blends the medical, health, social, and behavioral sciences while encouraging both quantitative and qualitative research techniques.⁶ It integrates intense individual mentoring with distance learning, a modality that in our experience is necessary to attract potential Native Investigators, for whom relocation is often difficult or impossible. The program weaves together didactic, experiential, and mentored instruction so that trainees can function as independent scientists working at the interface of health and culture. The program's key qualities have fostered a nurturing yet rigorous environment in which 5 cohorts of trainees have matured and thrived; a sixth cohort is currently being trained, and funding has been secured for a seventh and an eighth cohort.

The 2-year Native Investigator Development Program introduces American Indian and Alaska Native junior faculty to a core set of ideas, methods, and literature drawn from various fields to prepare them to conduct culturally appropriate research and succeed as faculty in competitive academic environments. Program activities include (1) regular seminars on issues in the health and healthcare of Native communities (commonly termed "Native health"), along with related topics critical to academic success; (2) intensive statistics and writing instruction; (3) mentored pilot studies; (4) frequent in-person group meetings; (5) regular telephone and e-mail contact with mentors between meetings; and (6) a mock review of trainees' grant applications, which constitute their final program product.

Native Investigators conduct 2 pilot research studies in Native health that provide opportunities to collaborate with tribes and tribal organizations. Within this framework, they pursue lines of inquiry that are personally and programmatically important, pertain to Native health disparities, and lead to external sponsorship. The first pilot project is a secondary data analysis completed during Program Year 1; the second pilot project is a primary data collection effort conducted during Program Year 2 to build on the findings of the first project. Data from the 2 pilot projects are used to prepare grant applications, which eventually undergo mock reviews.

Intensive weekly interactions with mentors are a distinguishing feature of the program, one that we believe is indispensable to the successful training of minority researchers. Each Native Investigator works with an individualized mentorship team that includes a primary senior faculty mentor, a secondary mentor who "graduated" from the program, a biostatistics mentor, and a writing mentor. Among the disciplines represented by primary and secondary mentors are anthropology, epidemiology, genetics, health economics, medicine, and nutrition. Both primary and secondary mentors have supervisory responsibilities for each Native Investigator's research activities, offering such career guidance as brainstorming appropriate publication venues and funding sources. Statistics mentors provide rigorous, hands-on support and conduct data analyses for the pilot projects. Each Native Investigator's complete mentorship team provides practical feedback on manuscripts and grant applications to maximize the trainee's likelihood of success.

Of the program's core faculty, 4 are from the University of Washington, 2 are from the University of Colorado Denver, and 1 is from the University of Arizona. Other senior affiliated faculty regularly attend meetings and augment the mentorship expertise of the core faculty.

Social network analysis

SNA is both a visual and a mathematical analysis of relationships. It has been widely used in the private sector to improve organizational function^{18,19} and is increasingly applied in program evaluation to describe the nature and extent of complex collaborative networks and bounded populations, such as WINR.^{11-13,16,17} Nodes, the basic elements in a network, represent definable entities, such as people, departments, and organizations. Links describe relationships, or flows, between nodes and denote their association; an example of a link would be a publication on which 2 investigators share authorship.

Social networks can also be the focus of quantitative analyses. The literature focuses on 4 metrics: 3 measures of centrality (*degree*, *betweenness*, *closeness*) and 1 measure of *network reach*. *Degree centrality*, defined as the number of direct connections for any individual node, measures activity on the network for each node. The other people to whom an individual is connected, and the importance and influence of these other nodes, also contribute to the meaning of degree centrality for any specific individual. *Betweenness centrality* describes the degree of connectedness that pertains to a node by virtue of that node's location "between" other nodes. High betweenness centrality describes the importance of a node as an intermediary in determining flow through the network. *Closeness centrality* focuses on the proximity of nodes to one another. In the case of WINR, closeness centrality reflects the pattern of direct and indirect ties among faculty and Native Investigators across cohorts. *Network reach* refers to the concept that not all network paths are created equal. Shorter paths are more important: key paths in networks are usually only 1 or 2 steps apart.

Each of these SNA indices is readily described mathematically, permitting traditional hypothesis-testing of anticipated network changes and enabling such changes to be tracked over time and visually displayed. Collectively, SNA metrics underscore the fact that the world in which we work is not one of many degrees of separation, but rather one of clear connections, making it critical to know who is in the network neighborhood, who needs our awareness, who can be reached, and which paths lead there.

Data collection

In 2006-2007, we collected information (described below) from all WINR members, including all Native Investigators who had completed at least 1 year of our training program ($n = 19$), and all core ($n = 6$) and affiliated ($n = 4$) faculty. For each WINR member, we collected information on manuscripts and grants pertaining to American Indian or Alaska Native health, broadly defined, using progress reports required by the funding agency. Our data collection protocol was considered exempt by the Colorado Multiple Institutional Review Board at the University of Colorado, Anschutz Medical Campus, which determined that the present study did not constitute human subjects research.

For manuscripts, we sought information about authorship status (first or co-author) and manuscript status (submitted, under review, in revision, resubmitted, in press, or published). Manuscripts in preparation were not included. For grants, we ascertained the role fulfilled by each WINR member (principal investigator, co-investigator, or consultant) and the status of each grant (submitted, under review, awaiting notice of grant award, funded, or not funded). All grants were included in the analyses, regardless of status. Next, WINR members received personalized reports with information on their manuscripts and grants, and were instructed to review and correct them and add pertinent information that was omitted.

After corrected reports were obtained from WINR members for both manuscripts and grants, we selected only those entries that described manuscripts or grants dating after the start of an individual's participation in the Native Investigator Development Program. The earliest

possible start date was 1998, when the program was initially funded, and the latest was February 5, 2007, when we began the current analyses. After data were entered, verified, and corrected as needed, the director of the Native Investigator Development Program reviewed all entries. Each individual was categorized in 2 ways. *Role* described the individual's program responsibilities as of February 2007. *Category* consisted of 4 levels: current core faculty ($n = 3$), past core faculty ($n = 3$), affiliated faculty ($n = 4$), and Native Investigator, with this fourth level including both past ($n = 7$) and current ($n = 12$) trainees.

Analyses

Visual and quantitative analyses were conducted by using the InFlow software package (Version 3.1, Toronto, Ontario), which uses mathematical algorithms to create a visual social network map based on the results of quantitative analyses.²⁰ We focused on individual mentors and mentees. Line width, node shape, location within the structure, and proximity of nodes to one another provide a wealth of information about the network. Node shapes were assigned to facilitate interpretation. In this analysis, 4 different shapes were used to represent each of the 4 different WINR categories noted above. A line between 2 nodes indicates a relationship; its width illustrates the relationship's strength or frequency. The location of a node shows the number of ties to other nodes in the network. For example, highly connected nodes are often found in the center of a structure, while nodes with fewer relationships are located on the periphery.

Our quantitative analyses were both descriptive and statistical. First, we performed the measures of network centrality (degree, betweenness, and closeness). Additional analyses for network reach were performed to determine the number of steps between any 2 nodes. Then, as appropriate (recognizing the limited statistical power in such a small dataset), one-way analyses of variance (ANOVA) and independent groups t-tests were conducted on the centrality measures by using the SPSS software package (Version 16.0, Somers, New York). Scheffé post hoc contrasts and comparisons were used following a significant ANOVA for any of the outcome measures to identify differences between groups, such as between WINR core faculty and trainees.

Results

Overview

Table 1 presents information on the role, academic discipline, tribal affiliation, and number of years involved in the Native Investigator Development Program for the 29 members of WINR. Figures 1 and 2 reflect the extent of interactions, primarily among co-authors and co-investigators, for manuscripts and grants, respectively. These 2 figures present social network diagrams, with nodes for each WINR member identified by geometric shapes. A line between 2 nodes indicates a working relationship on either a manuscript or a grant. Tables 2 and 3 provide data for the related analyses for manuscripts and grants, respectively.

Manuscripts: Visual analysis

Manuscript totals were simple counts calculated without regard to co-authorship. Members of the WINR network collaborated on 106 manuscripts. As shown in Figure 1, AT, an affiliated faculty member, and AP, a member of the most recent cohort of Native Investigators, were isolates. (These and all other uppercase letters in the tables and figures were randomly chosen; the individuals' actual initials were not used and remain confidential.) During the assessment period, these 2 individuals did not co-author any publications with others in the WINR group. For the remaining 27 individuals, no clear subgroups emerged, suggesting that WINR members collaborate across the entire network. At the same time, an examination of the width and number of lines reveals that both current

core faculty (AY, AQ, AL) and secondary mentors (AS, AR, AN, AE) were heavily involved in WINR manuscript preparation. Many of those on the periphery (e.g., AZ, AI, AD), like AP, had completed only the first year of the program when these data were collected.

Manuscripts: Quantitative analysis

The data in Table 2 supplement the conclusions drawn from Figure 1. As expected, current core faculty (AY, AQ, AL) had the most direct connections (degree centrality), making them the most active nodes in the network. For betweenness centrality, the 3 current core faculty (AY, AL, AQ), 1 past core faculty (BA), and 2 former Native Investigators (AF, AE) had more influence than the average person in the network, suggesting that these 6 individuals played powerful roles. The measure of closeness centrality again demonstrates that a similar combination of faculty, former Native Investigators, and secondary mentors had more direct access to all nodes in the network than others did. The members of this group had the shortest paths to all others (i.e., they were close to everyone else) and were in excellent positions to monitor information and activity flow in the network.

With regard to network reach, the network consisted of 1,296 individual paths, of which 166 paths (12%) were of length 1 (containing only 1 step), 798 paths (62%) of length 2 (2 steps), and 332 paths (26%) of length 3 (3 or more steps). Most (21; 72%) nodes in this network were separated by 2 steps or fewer. The fewer the steps between nodes, the less likely that information runs into a bottleneck (data not shown). Fewer steps generally imply that fewer opportunities exist for a node (e.g., an individual person) to block flow.

As no obvious subgroups emerged in Figure 1, we compared WINR role (current core faculty, past core faculty, affiliated faculty, and Native Investigators) on the centrality measures. Significant F-tests were found for all 3 measures: $F(3,23) = 11.6, 21.80,$ and 8.8 for degree, betweenness, and closeness centrality, respectively. Examination of the contrasts using the Scheffé procedure showed that current core faculty scored significantly higher than the 3 remaining groups on all 3 measures. On the other hand, Native and non-Native members of WINR did not differ on any of the assessments of centrality.

Grants: Visual analysis

Members of the WINR network collaborated on 83 grant applications. In the Native Investigator Development Program, involvement in grant applications begins only after manuscript development, so the number of isolates in grant productivity increased to 6. Figure 2 shows that, of the 23 remaining nodes, those representing the most recent Native Investigators and affiliated faculty were typically found farther from the center of the diagram. As with manuscripts, current core faculty, past Native Investigators, and secondary mentors were more central to WINR. Of note are the 4 highly connected individuals in a kite-shaped configuration at the center of the network (AY, AQ, AN, AL). These persons were in close proximity to one another and also, as denoted by the width of lines between the nodes, strongly bonded to others in the network.

Grants: Quantitative analysis

Table 3 presents the quantitative evidence on which Figure 2 is based, namely, that AY, AQ, AN, and AL are central to WINR grant productivity. Indeed, if we compare these 4 individuals with the other network members on the centrality metrics, they score significantly higher on all 3 measures: $t(21) = 6.5, 5.6,$ and 5.2 for degree, betweenness, and closeness centrality, respectively. When one-way ANOVAs were completed, again, the current core faculty had the highest centrality scores. Post hoc analyses showed that core faculty differed significantly from all other groups in degree and betweenness centrality. For

closeness centrality, however, core faculty had a higher mean score than the other faculty categories, but that score did not differ from the mean score of the Native Investigators. Again, no differences were noted between Native and non-Native WINR members. Similar to the reach findings for the manuscript network, most (19; 66%) of the nodes in the grants network were 2 steps or fewer from one another, indicating that few obstacles impede the flow of information.

Discussion

Racial and ethnic minorities constitute a tiny fraction of the NIH-funded principal investigators for whom race or ethnicity is identified,² even though minority groups make up 25% of the U.S. population.²¹ The situation for American Indian and Alaska Native researchers is arguably the bleakest. In 1999, the NIH funded 35,000 grants, 9 of which were awarded to Native researchers; by 2006, 24 grants had been awarded to 18 Native researchers.²² These troublesome figures are congruent with an Association of American Medical Colleges survey indicating that only 11 (0.1%) of all medical school faculty are Native, and these are predominantly at the assistant professor level or lower.²³

The underrepresentation of minority scientists among NIH-funded researchers has been attributed to their small numbers overall,²³ and is further exacerbated by the even smaller number of minority scientists who apply for NIH funding and their low rates of success.²⁴ Minority faculty tend to have more clinical, counseling, and administrative duties; are not typically engaged in research; and perceive their teaching and advising responsibilities as major obstacles to career progress.²⁵⁻²⁷ Also, minority physicians often choose primary care specialties and practice in underserved areas.²⁸ For minority faculty who are committed to addressing the service needs of minority students, housestaff, and their communities, the need to “publish or perish” may cause personal and professional conflicts.²⁹ In a study of barriers to NIH funding, minority investigators indicated that inadequate mentoring; lack of institutional support; and social, cultural, and environmental factors all posed obstacles to success.² The Native Investigator Development Program addresses these concerns by creating a supportive web of invested mentors and peers who are committed to reducing health disparities in Native communities.

Given the difficulty of retaining minorities in academia, the linkages demonstrated by the present analyses document the importance of involving our program “graduates” in mentoring activities, establishing support systems for trainees to decrease isolation, and educating and advising trainees about career development issues, such as funding, promotion, and institutional and sponsor policies. In this regard, strategies to retain minorities in academia often focus on decreasing their isolation by, for instance, creating a critical mass of minority faculty or offering diversity courses and research opportunities.³⁰ Not surprisingly, minority faculty are less satisfied with their careers and more often consider leaving academia than their white peers.³¹ Minorities in academia also hold lower ranks, move more slowly into senior positions, receive fewer NIH grants,³² and leave academia more frequently than their white colleagues.³³ The reasons for this situation are complex, but they reflect discrimination, a lack of knowledge about tenure and promotion, and a lack of mentors or role models.³⁴ The existing literature underscores the diverse needs of minority junior faculty, needs that our program addresses by training, informing, and linking Native trainees with committed, research-oriented faculty and role models. As this report demonstrates, SNA provides a tool to graphically depict the relationships formed as a result of the Native Investigator Development Program.

Traditional evaluative approaches rely on demonstrations of authorship¹⁷ and external grant support, but fail to acknowledge the meaning, value, and consequences of relationships

among mentors, mentees, and peers. SNA provides a natural approach for evaluating collaborative and mentorship relations like those in our program through its ability to map and measure complex relationships and flows.³⁵⁻³⁷ SNA delineates interactions between investigators in the form of geometric arrays, called “sociomatrices,” which differ from conventional data used in program evaluation.¹⁴ Standard multi-level analyses treat investigators as independent entities, perhaps organized within hierarchical structures, with data arrayed in matrices such that rows are individual investigators and columns are attributes (e.g., peer-reviewed publications) measured on investigators. A group of trainees might be described by cohort-level variables, such as total funding, while individual trainees might be characterized by the number of grants awarded to each person. SNA, in contrast, treats investigators as interdependent entities, with data on their interrelationships arrayed in a matrix such that the list of investigators and their attributes (i.e., grants and publications) are represented in the cells of the matrix by a value indicating the presence or absence of a relationship between them.

Research networks that promote collaboration among underrepresented minorities, especially those resulting from intensive mentorship programs, can be fruitfully evaluated by SNA. This technique has helped us to better understand the processes through which our program’s outcomes are achieved. In this regard, improving our program depends crucially on knowing how our networks are bounded, which faculty are the most central and influential members, which members provide linkages across networks, and which characteristics and roles distinguish them. SNA also documents the increasing role of past trainees in WINR as they take on more mentorship responsibilities and create their own collaborative webs. Finally, collecting rich qualitative and quantitative data, and then building on the insights gleaned from SNA, can help define and eventually model the observed relationships. Such models represent testable entities that, over time, can be used to assess any changes in the funding and publication landscape that result from the Native Investigator Development Program. SNA also holds promise for identifying new collaborations based on common research interests,³⁸ as exemplified by our program.

Limitations

This study has several noteworthy limitations. First, in the SNA of both manuscripts and grants, 3 highly connected people (AY, AL, AQ) account for much of the richness of the WINR network. Their high level of connectedness and influence over network flow reflect both the length of time they have spent in the program and their critical and central roles (not stated here for reasons of confidentiality). Second, we relied on conventional indicators of success, namely publications and grants, and did not consider other, likely crucial, community indicators of program success, such as outcomes of research or changes in clinical practices or policy. Third, although SNA is in some sense quantitative, its metrics cannot be substituted for a careful review of the visual representations and the formation of evaluative judgments on how best to interpret them. Finally, we studied only individuals in the WINR network, so we cannot draw conclusions about the potential role of colleagues outside the program in contributing to the manuscripts and grants we evaluated.

Summing up

The challenges and promises of research in academic environments are numerous. Most training programs neither adequately address the unique needs of minority investigators nor pave the way for their success. To alleviate racial and ethnic health disparities, we need to implement innovative scientific approaches, rigorously train and involve minority researchers, and develop new strategies that expand on existing concepts of evaluating career training programs. The effort described here represents a systematic method of documenting the far-reaching influence of one successful training program for American

Indian and Alaska Native researchers. Future research is needed to consider whether SNA can be extended to reflect tribal and community partnerships and whether including other personal and professional outcomes will enrich program evaluation. Additional studies are also recommended on the best use of SNA-based evaluation to longitudinally track the progress of the Native Investigator Development Program.¹⁵

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References

1. Smedley, B.; Stith, A.; Nelson, A., editors. *Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care*. Washington, D.C.: National Academies Press; 2003.
2. Shavers VL, Fagan P, Lawrence D, et al. Barriers to racial/ethnic minority application and competition for NIH research funding. *J Natl Med Assoc*. 2005; 97(8):1063–1077. [PubMed: 16173321]
3. Centers for Disease Control and Prevention. Racial disparities in nationally notifiable diseases--United States, 2002. *MMWR Morb Mortal Wkly Rep*. 2005; 54(1):9–11. [PubMed: 15647725]
4. AAMC files brief supporting University of Michigan admissions. AAMC Reporter. 2003. <http://www.aamc.org/newsroom/repo~er/march03/umichigan.htm> no longer available
5. National Institute of Mental Health. Five-year strategic plan for reducing health disparities. Bethesda, MD: National Institute of Mental Health; 2001.
6. Manson SM, Goins RT, Buchwald DS. The Native Investigator Development Program: Increasing the presence of American Indian and Alaska Native scientists in aging-related research. *J Appl Gerontol*. 2006; 25(Suppl 1):105S–130S.
7. Showstack, J.; Rothman, A.; Leviton, L.; Sandy, L. RWJ Foundation, ed *To Improve Health and Health Care: The Robert Wood Johnson Anthology*. San Francisco: Jossey-Bass; 2004. The Robert Wood Johnson Clinical Scholars Program; p. 105-123.
8. Christopher S. Recommendations for conducting successful research with Native Americans. *J Cancer Educ*. 2005; 20(1 Suppl):47–51. [PubMed: 15916521]
9. Mitchell TL, Baker E. Community-building versus career-building research: the challenges, risks, and responsibilities of conducting research with Aboriginal and Native American communities. *J Cancer Educ*. 2005; 20(1 Suppl):41–46. [PubMed: 15916520]
10. Brugge D, Missaghian M. Protecting the Navajo People through tribal regulation of research. *Sci Eng Ethics*. 2006; 12(3):491–507. [PubMed: 16909151]
11. Durland, M.; Fredericks, KA., editors. *Social network analysis in program evaluation: New directions for program evaluation*, No. 107. San Francisco: Jossey-Bass; 2006.
12. Eisenberg M, Swanson N. Organizational network analysis as a tool for program evaluation. *Eval Health Prof*. 1996; 19(4):488–506. [PubMed: 10186928]
13. Tuire P, Erno L. Exploring invisible scientific communities: Studying networking relationships within an educational research community. A Finnish case. *Higher Education*. 2001; 42(4):493–513.
14. Wasserman, S.; Faust, K. *Social Network Analysis: Methods and Applications*. New York: Cambridge University Press; 1996.

15. Gehlert, S.; Rebbeck, T.; Lurie, N., et al. Cells to Society: Overcoming Health Disparities: Centers for Population Health and Health Disparities. 2007.
http://cancercontrol.cancer.gov/populationhealthcenters/cphhd/documents/CPHHD_report.pdf
16. Friedman SR, Reynolds J, Quan MA, Call S, Crusto CA, Kaufman JS. Measuring changes in interagency collaboration: an examination of the Bridgeport Safe Start Initiative. *Eval Program Plann.* Aug; 2007 30(3):294–306. [PubMed: 17689334]
17. Newman ME. Coauthorship networks and patterns of scientific collaboration. *Proc Natl Acad Sci U S A.* 2004; 101(Suppl 1):5200–5205. [PubMed: 14745042]
18. Cross R, Borgatti SP, Parker A. Making invisible work visible: Using social network analysis to support human networks. *California Management Review.* 2002; 44(2):25–46.
19. Cross R, Parker AJ, Prusak L, Borgatti SP. Knowing what we know: Supporting knowledge creation and sharing in social networks. *Organizational Dynamics.* 2001; 30(2):100–120.
20. Krebs V. InFlow 3.1. 2008 Orgnet.com.
21. U.S. Census Bureau. The American Indian and Alaska Native population 2000: Census 2000 Brief. Washington, D.C.: U.S. Bureau of the Census; 2002.
22. National Institute on Aging. 20th Annual Summer Institute on Aging Research Draws Researchers from Diverse Backgrounds. LINKS: Minority Research & Training. Fall;2006
23. Minorities in medical education: facts and figures 2005.
http://services.aamc.org/Publications/showfile.cfm?file=version42.pdf&prd_id=133&prv_id=154&pdf_id=42
24. American Association of Medical Colleges. Women and minorities on U.S. medical school faculties. Washington, D.C.: The Association of American Medical Colleges; 1992.
25. Promotion and tenure of women and minorities on medical school faculties. *The American College of Physicians. Ann Intern Med.* 1991; 114(1):63–68. [PubMed: 1983936]
26. Suinn RM, Witt JC. Survey on ethnic minority faculty recruitment and retention. *Am Psychol.* 1982; 37(11):1239–1244.
27. Menges RJ, Exum WH. Barriers to the progress of women and minority faculty. *J Higher Educ.* 1983; 54:123–144.
28. Minority Graduates of U.S. Medical Schools: Trends, 1950-1998. Washington, DC: American Association of Medical Colleges; 2000.
29. Cregler LL, Clark LT, Jackson EB Jr. Careers in academic medicine and clinical practice for minorities: opportunities and barriers. *J Assoc Acad Minor Phys.* 1994; 5(2):68–73. [PubMed: 8032179]
30. Rogers MR, Molina LE. Exemplary efforts in psychology to recruit and retain graduate students of color. *Am Psychol.* 2006; 61(2):143–156. [PubMed: 16478358]
31. Palepu, A.; Carr, PL.; Friedman, RH.; Ash, AS.; Moskowitz, MA. Specialty choices, compensation, and career satisfaction of underrepresented minority faculty in academic medicine; *Acad Med.* 2000. p. 157-160.
http://journals.lww.com/academicmedicine/Fulltext/2000/02000/Specialty_Choices,_Compensation,_and_Career.14.aspx
32. Fang D, Moy E, Colburn L, Hurley J. Racial and ethnic disparities in faculty promotion in academic medicine. *JAMA.* 2000; 284(9):1085–1092. [PubMed: 10974686]
33. Minorities in science '93. Trying to change the face of science. *Science.* 1993; 262(5136):1089–1131. [PubMed: 8235628]
34. Wilson DE, Balotin J. Has the well run dry? Priming the diversity pump in PhD programs. *J Assoc Acad Minor Phys.* 1999; 10(2):27–33. [PubMed: 10826006]
35. Liberman S, Wolf KB. The flow of knowledge: Scientific contacts in formal meetings. *Social Networks.* 1997; 19:271–283.
36. Wagner C, Leydesdorff L. Network structure, self-organization and the growth of international collaboration in science. *Research Policy.* 2005; 34(10):1608–1618.
37. Crane, D. *Invisible Colleges.* Chicago: University of Chicago Press; 1972.

38. Cheatham, M.; Cleereman, K. Application of social network analysis to collaborative team formation; Collaborative Technologies and Systems International Symposium. 2006. p. 306-311.http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1644150

Figure 1. Visual representation of social network analyses for manuscripts produced between 1998 and 2007 by 29 current and former participants in the Native Investigator Development Program's Web of Indigenous and Native Researchers (WINR). The figure indicates that AT, an affiliated faculty member, and AP, a member of the most recent cohort of Native Investigators, were isolates. (These and all other uppercase letters in the tables and figures were randomly chosen; the individuals' actual initials were not used and remain confidential.) During the assessment period, these two individuals did not co-author any publications with others in the WINR group. For the remaining 27 individuals, no clear subgroups emerged, suggesting that WINR members collaborate across the entire network. At the same time, an examination of the width and number of lines reveals that both current core faculty (AY, AQ, AL) and secondary mentors (AS, AR, AN, AE) were heavily involved in WINR manuscript preparation. Many of those on the periphery (e.g., AZ, AI, AD), like AP, had completed only the first year of the program when these data were collected. See Table 2 for a numerical version of the results shown here.

Figure 2. Visual representation of social network analyses for 83 grant applications submitted between 1998 and 2007 by 29 current and former participants in the Native Investigator Development Program's (NIDP's) Web of Indigenous and Native Researchers (WINR). In the NIDP, involvement in grant applications begins only after manuscript development, so the number of isolates in grant productivity increased to 6. The figure shows that, of the 23 remaining nodes, those representing the most recent Native Investigators and affiliated faculty were typically found farther from the center of the diagram. Of note are the four highly connected individuals in a kite-shaped configuration at the center of the network (AY, AQ, AN, AL). These persons were in close proximity to one another and also, as denoted by the width of lines between the nodes, strongly bonded to others in the network. (These and all other uppercase letters in the tables and figures were randomly chosen; the individuals' actual initials were not used and remain confidential.) See Table 3 for a numerical version of the results shown here.

Table 1

Characteristics of Current and Former Participants in the Native Investigator Development Program, 1998-2007 *

Role of individual (alphabetic code) †	Discipline or expertise	Tribal affiliation	No. years with program	Category for social network analysis
Primary mentor (AQ)	Epidemiology	N/A	9	Current core faculty
Primary mentor (AL)	Anthropology	Pembina Chippewa	9	Current core faculty
Primary mentor (AY)	Internal medicine	N/A	9	Current core faculty
Primary mentor (AE)	Internal medicine	Rosebud Sioux	9	Native Investigator (former)
Primary mentor (BA)	Social psychology	N/A	2	Past core faculty
Primary mentor (AG)	Internal medicine/Economics	N/A	1	Past core faculty
Primary mentor (AU)	Genetic epidemiology	N/A	1	Past core faculty
Secondary mentor/affiliated faculty (AN)	Internal medicine	Cheyenne River Sioux	9	Native Investigator (former)
Secondary mentor/affiliated faculty (AF)	Internal medicine	Kiowa	9	Native Investigator (former)
Secondary mentor (AS)	Sociology	Cherokee Nation	4	Native Investigator (former)
Secondary mentor (AR)	Gerontology	Catawba	4	Native Investigator (former)
Secondary mentor (AX)	Ethics/Genetics	N/A	2	Affiliated faculty
Affiliated faculty (AB)	Family medicine/Epidemiology	N/A	9	Affiliated faculty
Affiliated faculty (AT)	Family medicine/Ethics	N/A	6	Affiliated faculty
Affiliated faculty (AO)	Statistics/Clinical trials	N/A	4	Affiliated faculty
Trainee (AM)	Medicine	Navajo	2	Native Investigator (former)
Trainee (AC)	Epidemiology	Eastern Band of Cherokee Indians	2	Native Investigator (former)
Trainee (AJ)	Nursing/Gerontology	Hidatsa/Sioux	2	Native Investigator (former)
Trainee (BC)	Surgery	Navajo	2	Native Investigator (former)
Trainee (AD)	Neuropsychology	Tsimshian	2	Native Investigator (current)
Trainee (AA)	Law	Squaxin Island Tribe	2	Native Investigator (current)
Trainee (AW)	Clinical psychology	HoChunk/Diné/Ute	2	Native Investigator (former)
Trainee/secondary mentor (AK)	Pediatrics	Muskogee Creek	2	Native Investigator (former)
Trainee (AH)	Internal medicine	Cherokee Nation	2	Native Investigator (former)
Trainee/secondary mentor (AV)	Clinical psychology	Inupiat	2	Native Investigator (former)
Trainee (BB)	Clinical psychology	Colville Confederated Tribes	2	Native Investigator (former)
Trainee (AI)	Neuropsychology	Eastern Band of Cherokee Indians	2	Native Investigator (current)
Trainee (AP)	Sociology	Hopi	2	Native Investigator (current)
Trainee (AZ)	Clinical psychology	Lumbee	1	Native Investigator (former)

* This table characterizes all faculty and trainees who participated from 1998 to 2007 in the Native Investigator Development Program, a career development effort for junior-level American Indian and Alaska Native researchers in the health sciences. To assess the program's effectiveness and identify the processes by which its outcomes were achieved, the authors used social network analysis to study the collaborative networks that

developed among current and former faculty and trainees. As the table indicates, participants represented a diverse range of tribal affiliations and brought broad expertise in health care and health services.

[†] Role as of 2007. More than one role indicates a change in roles over time. Each alphabetic code consists of a randomly selected pair of uppercase letters (e.g., AA, AB). Each pair of letters refers to a participant in the Native Investigator Development Program. Names and initials of participants remain confidential.

Table 2

Quantitative Social Network Analyses for Manuscripts Produced Between 1998 and 2007 by Current and Former Participants in the Native Investigator Development Program *

Role of member (alphabetic code) [†]	Degree centrality score [‡]	Betweenness centrality score [‡]	Closeness centrality score [‡]
Current core faculty			
AY	.769	.393	.813
AL	.692	.228	.765
AQ	.462	.107	.650
Former core faculty			
BA	.500	.093	.667
AU	.115	.000	.473
AG	.115	.000	.456
Affiliated faculty			
AB	.308	.032	.591
AO	.154	.000	.510
AX	.115	.000	.473
Trainees			
AF	.423	.051	.634
AE	.346	.041	.605
AR	.269	.008	.565
AN	.269	.005	.565
AS	.231	.003	.565
AK	.192	.000	.553
AV	.115	.000	.456
AM	.308	.006	.578
AJ	.154	.000	.531
BC	.154	.000	.510
BB	.115	.000	.510
AC	.115	.000	.510
AA	.115	.000	.473
AZ	.077	.000	.448
AW	.077	.000	.419
AI	.077	.000	.464
AD	.077	.000	.419
AH	.038	.000	.456
Average score	.236	.036	.543

* This table presents the results of centrality analyses of the network of health professionals who participated in the Native Investigator Development Program from 1998 to 2007. These analyses assessed the relationships among participants who collaborated on writing manuscripts for peer-reviewed publication, treating each individual participant as a node in the larger network. See Figure 1 for a visualization of the numerical results shown here. All centrality analyses have been normalized and range from 0 (absence of connectedness/betweenness/closeness) to 1.0 (fully connected/between/close). There is no level of significance in the analyses.

[†]Each alphabetic code consists of a randomly selected pair of uppercase letters (e.g., AA, AB). Each pair of letters refers to a participant in the Native Investigator Development Program. Names and initials of participants remain confidential. AP and AT are not included because they did not co-author any publications with other participants during the period of assessment.

[‡]Degree centrality measures the number of direct pathways or connections leading to an individual node in a network; betweenness centrality measures the frequency with which a node is located at the intersection of pathways leading to other nodes; closeness centrality measures the proximity of one node to other nodes.

Table 3

Quantitative Social Network Analyses for Grant Applications Submitted Between 1998 and 2007 by Current and Former Participants in the Native Investigator Development Program *

Role of member (alphabetic code) [†]	Degree centrality score [‡]	Betweenness centrality score [‡]	Closeness centrality score [‡]
Current core faculty			
AY	.727	.169	.733
AL	.636	.266	.733
AQ	.545	.069	.647
Former core faculty			
BA	.091	.000	.440
AU	.091	.000	.458
AG	.227	.000	.537
Affiliated faculty			
AB	.045	.000	.431
AO	.273	.010	.537
AX	.273	.000	.500
AT	.227	.004	.537
Trainees			
AF	.227	.000	.524
AE	.409	.063	.629
AR	.227	.135	.512
AN	.636	.129	.710
AS	.409	.028	.611
AK	.364	.016	.564
AV	.273	.017	.550
AM	.364	.019	.595
AJ	.045	.000	.344
BC	.136	.000	.449
AC	.091	.000	.393
AA	.318	.004	.512
AH	.273	.000	.512
Average score	.300	.043	.542

* This table presents the results of centrality analyses of the network of health professionals who participated in the Native Investigator Development Program from 1998 to 2007. These analyses assessed the relationships among participants who collaborated on writing proposals for funded research in the health sciences, treating each individual participant as a node in the larger network. See Figure 2 for a visualization of the numerical results shown here. All centrality analyses have been normalized and range from 0 (absence of connectedness/betweenness/closeness) to 1.0 (fully connected/between/close). There is no level of significance in these analyses.

[†] Degree centrality measures the number of direct pathways or connections leading to an individual node in a network; betweenness centrality measures the frequency with which a node is located at the intersection of pathways leading to other nodes; closeness centrality measures the proximity of one node to other nodes.

[‡]Each alphabetic code consists of a randomly selected pair of uppercase letters (e.g., AA, AB). Each pair of letters refers to a participant in the Native Investigator Development Program. Names and initials of participants remain confidential. AD, AI, AP, AW, AZ, and BB are not included because they did not write grant applications with other participants during the period of assessment.