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Exploring Women Engineering Faculty's Mentoring Networks

Ziyu Long, Purdue University

Ziyu Long is a doctoral student in organizational communication at Purdue University.

Prof. Patrice Marie Buzzanell, Purdue University, West Lafayette
Prof. Klod Kokini, Purdue University, West Lafayette
Robyn F Wilson, Purdue University
Jennifer C Batra, Purdue University
Lindsey B. Anderson, Purdue University

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Abstract

Research on mentoring has expanded from examination of traditional mentor-protégé dyads to developmental mentoring networks.[20,37] In these network approaches, the emphasis is on a constellation of career developmental and personally supportive relationships to design career experiences for focal individuals and to respond to the issues that these focal individuals, or mentees, express.[1,15] To study engineering women faculty' career experiences, we examine their egocentric mentoring networks,[29] that is, the individuals' self-reported linkages between themselves (i.e., "ego" or hub of the network) and career developmental "nodes"/mentors. We use a mixed methodological approach including multi-dimensional network analysis to map out the configurations of women faculty's mentoring network[11]and inductive analysis [6,7] to code our interview transcripts for mentoring relationships, women faculty's feelings about such relationships, and their perceived outcomes. Female engineering faculty members generally express dissatisfaction with the formal mentoring programs but endorse their informal and spontaneous/episodic mentorships emerging from their egocentric mentoring network. These women's mentoring networks are highly career-driven and consist of heterogeneous/diverse nodes, as well as multiplex ties that indicate multiple relationships between mentors and mentees. We provide theoretical and pragmatic implications of mentoring networks in the context of engineering faculty development.

Mentoring is a dynamic process that is defined as "a communication relationship in which a senior person supports, tutors, guides, and facilitates a junior person's career development" (p. 15).[23] It is traditionally characterized by reciprocity or mutuality of social exchange, developmental benefits linked to the mentees' work and career, and consistent mentor-mentee interactions over some period of time[20] as opposed to a one-way short-term relationship. Research on mentoring has expanded from examination of traditional mentor-protégé dyads to diverse situationally-based developmental mentoring networks.[20,37] In these more recent network approaches, the emphasis is on a constellation of career developmental and personally supportive relationships to design career experiences for individuals and to respond to the issues that these individuals, or mentees, express.[1,15]

Developmental networks are valuable for achieving a variety of career outcomes ranging from promotion and career advancement[39] as well as clarity of professional identity,[16] to more variability of advice than a primary or sole mentor can achieve.[22] In addition, developmental networks are found to be gendered and racialized in the sense that women and individuals of color more often experience challenges in gaining access to and maintaining reliable and meaningful mentoring networks. Current research mainly focuses on mentoring in corporate settings. In academe, there is a growing body of research on undergraduate mentoring. However, few studies explore faculty mentoring processes in academic settings and none describe how faculty mentoring networks are enacted in ways that advantage and disadvantage particular group members such as women in engineering.[44]

Our research expands the current literature by studying not only women faculty members' mentoring relationships but also women engineers' developmental mentoring network configurations. Furthermore, we explore an underresearched mentoring process known as episodic or spontaneous mentoring and mentoring moments.[1] As such, we contribute to much-needed empirical research on women in STEM disciplines (science, technology, engineering, and

math) that can help identify reasons for and strategies to combat women's unequal participation in these occupations and careers. We do so through theoretical and methodological lenses unused previously in academic engineering contexts. Specifically, we examine women's egocentric mentoring networks derived from qualitative interview data. Egocentric mentoring networks consist of individuals' self-reported linkages between themselves (i.e., "ego" or hub of the network) and their career developmental "nodes".[29] These network nodes can be resources, technology, and people that serve particular roles connected with departments, associations, institutions, agencies, and other organizations.[11] Guided by multiple network theories such as homophily, embeddedness, and social capital, our goal is twofold: to understand how women engineering faculty construct their mentoring networks; and to display and analyze women engineering faculty's mentoring network configurations. To provide further context for these aims, we next supply an overview of mentoring research and social network constructs and theories that concludes with our two research questions. We follow this literature review with a detailed description of our research methods. We then present the findings based on the content and attributes of nodes as well as ties within the ego-centric mentoring networks. We conclude our paper by discussing our theoretical contributions and our findings' pragmatic applications to women engineering faculty's career development.

Literature review

Mentoring research has broadened from its traditional dyadic focus to examine support provided to mentees by a "constellation" of mentors from different life domains.[21] Individuals may have several mentors who have different foci to fulfill various mentoring needs of the individuals (e.g., general career advice, promotion, teaching, researching, or work-life issues). Mentoring networks are essential to compensate for the dissatisfaction of traditional mentoring relations, socialize new organizational members, cultivate peer mentors, and facilitate collaboration and innovation.[15,30] In mentoring networks, mentors and mentees are encouraged to work in "non-hierarchical, collaborative, cross-cultural partnerships to address specific areas of faculty activity such as research, teaching, working towards tenure, and striking balance between work and life" (p. 58).[40] Mentees, in particular, are advised to take an active role in seeking multiple mentors who can address specific needs. These recommended active strategies differ from the more passive roles expected of protégés in traditional mentorships where knowledge was imparted unidirectionally. Developing mentoring networks are even more important for individuals who pursue academic careers, given academe's emphases on networking for research opportunities and life-long learning.[14]

Although studies have theorized the definition and benefits of mentoring networks, little empirical research has explored the configurations and processes of ego-mentoring networks. Moreover, current developmental network research tends to focus on the mentoring network based on formal or informal mentoring relationships. Less attention has been given to mentoring episodes or mentoring moments, defined as short-term developmental interactions that occur at specific points in time.[17] Mentoring moments may arise "when two or more presences engage in a dialogue about a scholarly opportunity or a career choice" (p. 97).[33] It is through the interaction with multiple ''mentors of the moment'' that faculty mentees expand their competencies and their beliefs about future career possibilities.[2] In our empirical analysis of the ego-mentoring network, we explore how formal, informal, and episodic mentoring relationships emerge and interact with each other in women engineering faculty's mentoring networks.

Mentoring appears to be especially critical for women because of the subtle barriers to career advancement that they face.[32] In the engineering higher education context, women faculty encounter male-dominated work practices, standards, and norms throughout their education and careers.[34] Women faculty's success in developing healthy mentoring relationships can significantly and positively affect several outcomes: increasing the talent pool in academic programs; creating more diverse communities in institutions of higher education; and leading to more equal access to resources and rewards in academe.[8] In network literature, research indicates that women generally have less access to professional networks as compared to men and that women's networks are usually not well embedded into organizational power centers.[35] Studies have found that women faculty in science and engineering are less likely to be mentored than men [31] and are less likely to engage in everyday conversations about their work and career.[18] In response to the lack of access to mentoring resources, women strategically build their mentoring networks to seek out needed information and support. Ibarra[24,25] found that women tend to seek other women as friends and supporters and they are more inclined to build connections with men for instrumental or career purposes. Ragins[36,38] found that it is quite common for female mentees to pair with male mentors in order to gain entry into the 'old boy's network' in male-dominated occupations, in which men usually have higher status, pay, positions, and influence than women.[42]

In addition to gender issues, literature shows that individuals of color are particularly likely to suffer setbacks from a lack of career guidance.[4] For instance, in the workplace, managers of color are less likely to have intimate informal relationships than white managers of either sex.[25] Specifically, black women find informal social networks to be less accessible.[3,10] As documented by mentoring literature in academic settings, underrepresentation of minority groups creates a special challenge in finding mentors outside of the majority population and within underrepresented minority members' respective departments.[9] Underrepresented faculty members have difficulty finding mentors, feel lonely and isolated, and experience subtle and overt discrimination in their daily lives.[32]

As noted before, this study explores women faculty's mentoring experiences through their egocentric networks. An egocentric network is defined as "a focal persona or respondent (ego), a set of alters who have ties to ego, and measurements on the ties from ego to alters and on the ties between alters" (p. 53).[42] In mentoring networks derived from interview data, the ties are individuals' self-reported linkages between themselves (i.e., "ego" or hub of the network) and mentoring/career developmental "nodes", that can be human or non-human.[11,29] To explore the configurations of engineering faculty members' mentoring networks, we adopt multi-dimensional mentoring network model suggested by Contractor, Monge, and Leonardi (2011), that is, a network consisting of multiple types of nodes (multi-modal) and multiple types of relationships (multiplex)[11]. We argue that the multi-dimensional network model can provide a more holistic and realistic picture of mentoring networks because it consists of both human and nonhuman actors (e.g., websites, books, social media) and it displays mentor-mentee relationships as very dynamic and existing in multiple socially embedded relationships (e.g., mentor and mentees can be friends and also research collaborators). In analyzing women faculty's egocentric mentoring networks, one can look at network *size* or the number of ties linked to the ego, *diversity* or the number, type, and uniqueness of the mentors, and *strength* or the emotion, reciprocity, and frequency of interactions in networked relationships.[27,41]

Multiple theories can be used to explain the configurations and emergence of particular networks.[29] Homophily theory indicates that individuals tend to select others who are similar to

themselves (e.g., in age, gender, location, education, prestige, social class, tenure, and occupation) in their social network. Shared demographic characteristics, including race, sex, social class, religion, and values, are critical to building social networks because social connections between individuals are based on social processes and personal preferences. [28] In mentoring contexts, women mentors and mentees likely seek those with whom they share similar backgrounds, depending on the specific context in which mentoring occurs. Social capital (structural hole) theories argue that individuals make efforts to connect with people or organizations that are not linked with each other so that they can enhance autonomy and locate career development opportunities.[5,19] Social capital literature indicates that heterogeneous or diverse networks extend individuals' exposure to non-redundant, novel information, which is associated with greater participation and career mobility opportunities.[19] Guided by the theory of social capital, individuals may actively diversify and expand their mentoring networks to benefit from and expand their network positions. Particularly, establishing mentoring ties with nodes external to mentees' departmental and organizational networks might be useful in increasing mentees' exposure, visibility, and career mobility.[13]

Guided by mentoring literature and different network theories, we explore how women engineering faculty members reach out to and accept mentoring sources (i.e., proactive and reactive processes). Specifically, we ask the following research questions: (RQ1) how do women engineering faculty construct their mentoring networks? and (RQ2) what are engineering women faculty's mentoring network configurations?

Methods

This paper is part of a larger project to assess the revised formal mentoring programs designed and offered by the College of Engineering at a large Midwestern (U.S.) university and to study the mentoring experiences of faculty members in the STEM discipline. Our paper focuses on women faculty members' mentoring experience from a network perspective. Seven tenure-track women faculty members from the College of Engineering agreed to participate in our study (see Table 1). Participants represent five different engineering specialties in the College. Two of our participants self-identified as underrepresented minority group members (28% of the total sample size). Among the seven faculty members, six were tenured and promoted (85% of the total sample size) with two being full professors (28% of the total sample size).

To understand women engineering faculty members' mentoring networks, we conducted in-depth interviews, and integrated inductive analysis and multimodal network mapping at the data analysis stage. We used a semi-structured interview protocol (see Appendix) to encourage a conversational flow and to focus on issues deemed important by our interviewees. Upon gathering all the data, we contracted with a professional transcription service. We verified transcriptions against the audio recordings before masking identities through use of pseudonyms and through deletion of other identificatory details.

The 7 semi-structured interviews were approximately an hour each (average: 50 minutes with a range of 30-80 minutes). Although the interviews were not designed to collect network data, we noted that the network data were robust, meaning that our questions elicited a variety of mentoring relationships with different participants, forms (e.g., formal, informal, episodic), intensities, reported reciprocities, and rich details to round out our understandings of network configurations. We argue that such spontaneously generated network data emerging from our in-

depth interviews indicated which nodes (mentors) and ties (relationships between mentors and mentees) were most salient to and memorable for our interviewees and, therefore, were perceived as most critical to our participants' career development at this point in time.

To analyze our data, we first utilized inductive analyses whereby we coded our interview transcripts for mentoring relationships, their feelings about such relationships, and their perceived outcomes.[6,7] Our participants reported indicators of their subjective and objective career success, in addition to their faculty status. They described not only their productive relationships but also additional resources that they considered necessary for current and future career development. We individually and collectively examined these data in this way to provide the context for the network configurations that we next developed in response to our research questions.

For our two research questions, our data analyses were guided by multi-dimensional network mapping frameworks and examination of data for mentors and mentoring resources identified by mentees in the interviews. Our participants reported their nodal structural relationships as well as the attributes of the nodes. Before mapping the networks, we re-read transcripts and discussed our general mapping strategy based on our definition of a mentoring network. As the interviews are not initially designed to understand participants' mentoring networks but their general mentoring experience, we could only map out the mentors/mentoring sources that participants indicated explicitly in their interviews.

To do the mapping, we adhered to the following procedures. First, researchers read each transcript separately and took notes about the ties (i.e., formal, informal or episodic mentoring relationship, frequency of communication, through what channel), nodes (i.e., the gender, race, institution of the mentor, nature of the mentoring source), as well as the content of the exchange and the governance principle of the mentoring network from each participant's perspective. Second, the researchers exchanged notes and discussed the nodes and ties for each network to make sure that all the information relevant to each mentoring network was extracted from the interview. The researchers then mapped out the networks by drawing the egocentric mentoring network in the shape of a star network with the ego or research participant in a central location. After the figures were created, the research team revisited all the transcripts to search once more for contextual details and critical aspects that provided insight into specific participants' mentoring configurations. The figures were revised accordingly with all changes being associated more with participants' own language choices than with additions or deletions of nodes. Finally, one of the research team members re-created the hand-drawn and revised mentoring networks using computer software.

In these figures (see Figures 1-7), the ego/participant was located in the center of the graph and denoted in circle with her pseudonym. The mentoring nodes were denoted in: circles, representing human mentors; squares, representing nonhuman mentors; parallelograms, representing group mentors; and triangles, representing individuals whom our participants mentor. In graphing these figures, we avoided use of specific information about mentors that might reveal the identity of our participants. However, we noted the gender and affiliation of the human mentors (e.g., department, university) when that information was provided in the interviews. In terms of the ties in the network, we used straight lines to denote formal mentoring relationships, dotted lines to denote informal mentoring relationships, and dashed lines to denote episodic mentoring relationships. Although we did not ask our participants to rate the strength of the relationship, we assessed the strength in our analysis based on the remarks of our participants about the how often/important/many channels they used to connect with their mentor from the

qualitative interviews. We have also mapped out multiple relationships if the participants noted such relational differences explicitly (e.g. "she's not only my mentor but also a close friend"). We did not map the directions of the ties as the reciprocity between mentoring parties are highly fluid and contextual during the span of a relationship. The underlying circle represented the official departmental boundary and the hexagon represented the institutional boundary (university). We spaced out these relationships by equally dividing the circle into n part (n=mentoring nodes). We note that the distance between the nodes did *not* indicate any form of proximity. In short, the mixed methodology not only allowed us to understand our participants' mentoring network configurations but also their reasons and perceived outcomes of these networks.

Results

In this section, we present our findings based on the inductive analysis and multi-dimensional network analysis. Our research questions asked: (RQ1) how do women engineering faculty construct their mentoring networks? and (RQ2) what are engineering women faculty's mentoring network configurations?

Women engineering faculty constructions of their mentoring networks

In general and in response to RQ1, women reported that they faced challenges in finding and sustaining meaningful mentorships in male-dominated STEM disciplines. Women engineering faculty expressed some dissatisfaction with the formal mentoring programs and sought out mentoring on their own—taking what they perceived to be lacking and using these insights to cultivate and recognize emergent informal mentoring opportunities. Some participants learned from trial and error and by observation, but others actively constructed their own mentoring networks to gain the connections they needed to develop their knowledge, skills, and abilities. Women engineering faculty's mentoring networks were usually driven by goals related to career advancement, namely, tenure and promotion as well as promotion to full professor processes. In response to RQ2, women engineering faculty's network configurations displayed of highly heterogeneous nodes and multiplex ties.

Lack of meaningful formal mentoring structures. At the department level, women faculty reported that the formal mentoring structure was either non-existent or not very helpful to their overall career and personal development, with only one exception. They described the existing mentoring programs as aligned with meetings scheduled during the academic year to track untenured faculty members' progress toward promotion and tenure (and then to track associate professors' progress toward promotion to full professor). Because the mentoring had one main purpose, our participants felt that it could only meet some of their mentoring needs. As described by Maria, an associate professor,

> so they do have a so-called mentoring program, but the extent of it is that every year they assign two different faculty members—so every year, they change—and they just talk to you just one time before the annual evaluation for faculty. So, like a month before, they discuss performance; two faculty members go in a neutral room with your CV, and they discuss with you your past performance. And then after that discussion, they go, with that information, into the primary committee, where they present your case.

For Maria, the rotating faculty "mentors" cannot provide her with long-term mentoring relationships based on mutual trust and respect. She perceived the formal system as inflexible such that she cannot receive just-in-time career advice and emotional support.

According to our interviewees, some reasons for the less satisfying formal mentoring structure were: (a) lack of commitment and investment to sustaining the mentoring program at the department level ("in terms of formal mentoring, we don't have any guidance. It's sort of like on an incident-by-incident kind of mode, then you need guidance counseling or something, you know"), (b) lack of knowledge on the part of the senior faculty members about how to mentor well ("they just don't know how to do it"; "they don't have a heart for it"), and (c) lack of a collegial, collaborative, and inclusive culture that promotes mentoring ("this is a very isolated- and isolating environment").

Several participants emphasized the important of cultivating a culture that promotes mentoring. Zoe, a recently promoted associate professor, talked about a culture of collegiality that could be "half the mentoring story." She continued, "because that [a culture of collegiality] is the thing that makes the environment for a lot of the things that go with mentoring, and if that's not there, then that does push mentoring into these behind-closed-doors kinds of experiences, or off-of-campus kinds of experiences, or phone-call-to-a-friend." Berta, an associate professor, also commented on the influence of culture on the departmental mentoring practices. She noted the irony in attempts to construct collaborative processes (mentoring) within competitive individualistic cultures (engineering) with a laugh. She indicated that the individualistic culture in engineering may create some resistance to mentoring, "because everyone is really trying to be the best on their own, and individualism is very much valued in engineering, and that goes against helping somebody else. Because you give a leg up to somebody else, you're falling down the stairs yourself (laugh)."

Working in this competitive culture, many women felt isolated from workplace mentoring networks. As articulated by Rachel, a full professor, "that was one of the things that I guess I felt when I was a very junior person: isolated. I didn't feel there was anybody I could trust to talk to, you know, and frankly, things are much more complex now than they were when we were assistant professors; much more is demanded." Similarly, Zoe expressed the sense of isolation and disempowerment coming in as an untenured faculty member, "I felt like I was in the weeds and I had to figure it out on my own. And, you know, [the senior faculty members] didn't offer examples, didn't talk to me. So I think maybe they thought they didn't have anything to offer. But I didn't receive any mentoring whatsoever."

Emergence of informal mentoring networks. Like Zoe and Rachel, the women we interviewed were able to figure things out on their own in response to the less satisfying formal mentoring structure. When asked how they navigated their academic careers, some participants said that they learned from trial and error and from observing others. As described by Rachel,

> Making mistakes (laugh) … See what works. Oh, no, I'll try something different tomorrow (laugh). Um … I think in my case, mostly I observed people that I saw the outcome of, you know, people who were more senior, saw the outcome of their engagement with different stages of their career.

Others, especially untenured faculty members, actively sought out mentors and other resources to build a developmental mentoring network. As a recently recruited assistant professor, Nakala actively sought mentoring, "So I'm pretty active with—if I see someone or hear someone that says anything, I'll seek them out, you know, because I'll try to make a connection with them,

too." She normalized a proactive mentee role as an inherent part of contemporary academic jobs, in contrast to senior women faculty who characterized active seeking of mentoring relationships as "showing weakness" or "a matter of personal style". In Nakala's own words,

> I think being a professor and seeing what's normal, I don't worry about things like that. It's normal to want to contact people and sit down and talk with them. It's normal to … you know, it's what you should do … it's inherent. This process of getting tenure requires—it's like it requires that you talk to people, like it is part of the … like this is what you should be doing. You should be talking to people. You should be getting advice from people. It's expected that you're looking for advice. So it's sort of the culture of what it means to be a new professor, at least this is my perspective and this is what I understand it to be.

Like Nakala, Zoe also actively sought out mentoring when she was an assistant professor. She organized an informal peer mentoring network structure as there was no formal mentoring program in place at the department level. Zoe shared one of her peer mentoring episodes,

> when my tenure stuff was official, I just did an open invite at a coffee shop away from campus, so it was kind of in a protected place, and I said, "Anybody who wants to come and talk to me, you can ask me anything you want about my process and my experience," and I gave them a copy of my stuff, and pretty much all the assistant professors showed up. It ended up being like a two-and-a-half-hour-long discussion.

In addition, Zoe and a couple of other untenured faculty members engaged in peer mentoring during their writing sessions at a local coffee shop (see Figure 3). As discussed by Zoe,

> A set time every week where we're at a coffee shop, writing papers, and often that becomes, you know, going around and asking people advice about stuff, the kind of advice like, "Here I'm writing this paper, what do you think of this?" kind of stuff. So, it's a real mix of advice. You know, "How do I deal with this particular situation?" or "I've got this troublesome student," or "I'm working on this paper or proposal, what do you think?" But it's a time where we're kind of all in that space and we're all kind of working (laugh).

As Zoe put it, "those combinations of things made sort of a, you know, figure-it-out, make-your-own kind of mentoring situation."

Career-oriented mentoring network content. Our participants' reported mentoring networks were highly career-oriented and driven by departmental and college requirements for career advancement. As illustrated by Nakala, an assistant professor, mentoring enabled her to focus on what was important for promotion and tenure:

> In the department, the most important mentoring relationship, or what I'm trying to get out of it, is just making sure that I have feedback when it comes to research, and doing the things and getting properly acclimated to the department's culture. That's important to me from the mentors here, and making sure that I'm doing the types of things that really matter when I do annual reviews.

Our participants indicated that discussions with their mentoring partners usually centered around tenure and promotion application materials and processes, grant writing, research project management, teaching, professional networking, and the handling of interpersonal relationships with colleagues and students. Because the mentoring networks were tightly connected to career development and advancement, we found differences among the senior (tenured, older) and junior (untenured, typically younger) faculty members. Junior faculty members were more active in building their mentoring networks not only for short-term goals but for long-term and sustainable career progress. Nakala, a junior faculty member, explained, "Because I know for me

right now, this is about foundation building, and so … yeah, I just try to take advantage of everything that I think is going to be helpful in me building that foundation." Indeed, faculty had different mentoring needs at different stages of their careers, as said by Berta, a senior associate professor who had been employed by her university for over two decades: "so if somebody coming in was hired, you know, new to the department at assistant level, the kind of mentoring would be different than somebody who is in my position, who's been here 20 years and kind of knows what goes on here." Rachel, a full professor in the College of Engineering, further elaborated on the different needs at different times theme by talking about the ways her major roles in mentoring networks have changed from the mentee to the mentor (see Figure 5),

> As an assistant professor, not thinking as a woman, as you go through that process, then you have a lot of experiences. They don't make you an expert in mentoring, but it's a start, because you know what some things that are needed. And so then as an associate professor, then you start that process of helping to mentor. As a full professor, I was fairly soon thereafter the head of our group within the department, and we had our own graduate degree and I recruited faculty, and so I had responsibility for recruiting and mentoring faculty, and so that's when probably I learned more, was when I had a clear responsibility and so it became a part of my professional life.

In addition, our findings supported previous literature that under-represented minority faculty members generally perceived a stronger need for mentoring to be successful in their academic careers. As illustrated by Yolanda, a woman faculty of color,

> You know, like if you're the first, if you're the only, you're going to have to create something new because there's nobody in front of you to do anything—I mean to tell you how to do it that particular way. So you have got to create your own path, even in mentoring… I think be proactive, that's very important. Identify your networks early. Look for diverse mentors and people who really are advocates *for* you.

Interestingly, when asked about "who would you go to discuss issue related to work-life management," all of the women faculty replied that they did not talk about work-life issues with people in their departments. Berta, for instance, said that she had no one to talk to about work-life concerns, "I think because there is nobody to go to, I wouldn't even know where to start. I mean, I might grumble with my colleagues, but most of those colleagues are not my mentors. I'm theirs (laugh) … I don't have kids, so I don't have those same issues that I think many of my colleagues have." Ellie, a full professor, responded similarly, "nobody. I've been in such an unusual situation my entire life that I just make my own path, and if other people don't like it, that's their problem (laugh)." Rachel strategically set the boundaries between professional and personal,

> I did not seek out in my personal life to have people that were in my profession. I mean, it's fine if it happened, but it wasn't really something I sought out. And there was a time when I was going through some difficult situation and I just really didn't want to have people in my profession to be—I didn't want them crossing that line. I just didn't want . . . didn't want them to—because it just makes it more difficult.

These women indicated that they have been very careful about their handling of work-life boundaries to "play it safe." As elaborated by Maria in her example,

> And if my son was sick, I usually would say I'm sick. Although I don't think there is a reason here in this department; people are family-friendly in general, but I was just worried about biases that are … if you are a woman and you say your child is sick, you appear like, oh, you are on the mommy track, your child is sick all the time. And I would try to kinda

> avoid discussing these kind of problems with anybody, and that's kind of how I started..., just better to be safe.

Women engineering faculty's mentoring network configurations

In response to RQ2 that asked about women engineering faculty's mentoring network configurations, we found that our participants' ego-networks were heterogeneous and multiplexed.

Heterogeneity in women's mentoring networks. Women faculty discussed mentoring networks that consisted of more heterogeneous nodes than homogeneous nodes in terms of common identity markers such gender, race, academic ranking, affiliation, and mentoring function. In other words, nodes in women's mentoring networks were quite diverse. The heterogeneity of the mentoring networks was illustrated in the following quote from Ellie (see Figure 2),

> The last few years, there have been some people that I've had a chance--for example, Dean XX here and President XX. So, in more recent years, there have been a few more women, and . . . a couple of times as a faculty member at XX University there were a couple of men that I worked with who recognized they could actually provide some useful help to me.

Our participants did not necessarily seek out women for their mentoring networks, as would be consistent with previous literature. This pattern may have occurred in part because there were not many women in the department, as Ellie said, "Because there are so few women in engineering, particularly so few senior women, having men be effective mentors of young women faculty is something that we need to look at." Additionally, our participants noted that simply having a female mentor would not guarantee that they would receive effective mentoring (admitting implicitly that the gender stereotype of women being more nurturing and interested in "women's issues" would not necessary occur). When asked if she had a woman mentor, Maria replied, "I didn't have any female [faculty members to talk to]. My research advisor, my Ph.D. advisor, was a female, but I didn't feel she was helpful in terms of … she didn't really care about female issues, I guess (laugh)."

Indeed, as noted by Ibarra in her research of women's professional networks, women have been forced to forgo their propensity for homophily in terms of their instrumental relationships in the workplace, and as a result of social exchange constraints and needs to be connected with an institution's predominantly male power. [24] In our sample, several participants reported that their mentors, usually white male professors, were the heads of their departments/ schools/university. Participants considered having mentors with status and credibility who had the mentees' best interests at heart to be very beneficial to their professional development. Berta talked about her mentor who also was department head (see Figure 1): "I would say he was as much of a mentor as anybody, because he got me over those hurdles early on in my career of how do you write grants, how do you get through your committee work, and all this stuff. It was more informal, it was never a formal arrangement." Maria also had an informal mentoring relationship with the department head (see Figure 7), "so I was comfortable with a certain faculty member which actually was the department head, and personally, whenever I had a problem, I felt comfortable going and asking for help, and I knew that he would always support me and give me advice." Zoe, however, pointed out the "tricky part" of her mentoring relationship with the department head: "every department has politics… People started putting little things together in their head about like, 'Well, you're chumming with the head, so you must get all sorts of extra stuff.' And I don't."

The nodes of women's mentoring network are also heterogeneous in terms of their affiliations. In other words, women's mentors come from diverse institutions and agencies. Almost all participants have trusted mentors outside of their departments and/or the university with which they were affiliated. Ellie, for instance, talked about the need to include people outside of the institution into one's mentoring network to be successful in engineering, "I think mentoring needs to include connections to the outside—connections to the funding agencies, connections to people who might collaborate with you on research, probably international connections because a lot of the science and engineering now is international. So, probably the connections are the most important thing." Nakala also talked about the importance of having outside mentors to receive different perspectives on issues and a safe space to ask questions. She shared a story about interactions with one of her mentors,

> She's like a provost or something at another university, and she would just help me answer those questions like how do you negotiate and how do you—you know, just some of those practical things…that's one you can set up times to call, you can call at any time and just say, "Hey, how do I handle this situation?" or any, like, sort of the questions that you would want to ask but not necessarily that's departmental, that you'd want to ask someone in your department.

In addition, the nodes in the women engineering faculty's mentoring networks were both human and nonhuman. The nonhuman mentoring nodes included books, online technology, workshops, and university-wide mentoring networks and resources (e.g., ADVANCE). Maria, for instance, consulted books for mentoring advice (see Figure 7), "I didn't have lots of people to talk to, so I bought a bunch of books. I read about what should I do, how should I run my lab, instead of asking people." Nakala used an online community of faculty members as a mentoring source (see Figure 6):

> It helps us to stay on track with what's the most important as an academic, which is your research, your writing, and making sure you're making progress with that. It's like an accountability system. But then there's also a mentoring component, where you can call the director at any time and ask the crazy questions, the weird questions, and get good feedback. So that's a mentor outside the university.

Finally, participants assigned different functions to their mentors, as Ellie said, "because one person can't provide everything that you need; you need to talk with other folks." Two of our seven women faculty members explicitly talked about their strategies in constructing their mentoring constellations. For instance, Nakala said she learned that women faculty need to have nine categories of mentors, "it's not like I have the chart in front of me, but I have an understanding that mentors should serve multiple functions." Yolanda also shared her strategy to engage her mentors (see Figure 4),

> My advocates have different roles for me…There are people who understand administration, so when I need to talk to someone about administration, I can talk to those people. When I talk about grant writing, you know, there are certain people I would talk to. Just negotiation strategies, you know, I talk to people who are very familiar with policies, politics, and things like that. They are just different.

Multiplexity of ties in women's mentoring networks. In addition to heterogeneous nodes, female engineering faculty members usually described multiplex ties to their mentors, that is, our participants usually had other relationships with the mentors in addition to the mentoring relationship. Berta shared her story about how she got to know one of her mentors through a

research collaboration, "I was very lucky to have a colleague … three or four years into my assistant appointment, who got a very large grant that I was kind of dragged into, fell into by accident, who really showed me how to run a very large grant and how to do different kinds of research." In this case, Berta received mentoring as part of a seemingly natural process when she worked with her colleague in this research project. Reflecting on this experience, Berta now considers her colleague to be an important mentor to her (see Figure 1). Other participants noted that their mentors were people with whom they taught and/or collaborated in various ways.

Although most of the reported multiplex ties between mentor and mentee were professionally oriented, women faculty also shared friendship ties with their mentors, especially if they were peers. As Zoe put it, "I think in many ways most of the people that I identify as mentors have a similar kind of relationship—that they're collaborators, they're friends, they're the person you pick up the phone or stop by their office and say, 'Hey, can I talk?'" Indeed, a meaningful mentoring relationship needs to be based on mutual trust and nurtured in interactions. Yolanda talked about the importance of relationship building in mentoring,

> I've developed relationships with people, so I do think that a lot of it comes from, like I said, relationship-building, and I know them (mentors) … on, many times, more than just a surface level; you know, I've gotten to know them outside of a professional environment, or I've gotten to know them outside of that traditional environment, so it's a relationship.

As we can see from these women's stories, their mentoring relationships overlapped their professional and personal lives, thus making their current ties in the mentoring network multiplex. The forming of their mentoring relationships was based on mentoring episodes, that is, short-term developmental interactions that occurred at specific points in time that yielded a mentoring relationship through accumulation. [17] However, it is important to note that many times these mentoring moments serve as just-in-time advice episodes and do not create long-term relationships.[1] From a network perspective, these mentoring episodes may occur with the weak ties of the women's social network. When episodic mentoring interaction occurs, the ties between the ego and node may be activated/linked. However, as these ties exist "in the moment," it is therefore hard to capture in the reflexive mentoring networks presented in this paper.

Discussion

Women engineering faculty still face a chilly climate [26] in their workplaces and institutions. This chilly climate can be exacerbated and/or lessened through development of formal, informal, and episodic mentoring relationships. In response to a somewhat unsatisfying formal mentoring structure, our participants construct their mentoring networks based on their own needs at their different career stages. As the first empirical study to use a multidimensional network approach to analyze women engineering faculty's mentoring experiences, we found that women faculty's mentoring networks are multimodal and multiplex. First, their mentoring networks consist not only of highly heterogeneous human actors/nodes in terms of gender, ethnicity, affiliation, and assigned mentoring roles but also of various non-human actors/nodes such as books and websites. We speculate that these unique configurations of human-nonhuman nodes in these women faculty's mentoring networks are results of both choice heterogeneity (based on individual preferences) and induced heterogeneity (based on availability and constraints). In other words, female faculty members may strategically expand and diversify their mentoring networks to harness potential network social capital. At the same time, they may have to include heterogeneous nodes in their mentoring networks because homophily mentoring nodes are not

available. However, our participants implied that homophily can go beyond traditional identity markers such as gender, race, and academic ranking to delve into world view, goals, personality, and common interests.

Second, these women's mentoring networks are multiplex as ties in their mentoring ego-networks usually contain more than one relationship. In addition to their career developmental network ties, mentor and mentee are linked by several types of ties (e.g., friendship, collaborator, and service on the same committees). These multiplex ties between mentor and mentee can be beneficial as multiple relationships strengthen the mentor-mentee bond and provide different venues for episodic mentoring to emerge naturally. For instance, faculty may engage in multiple mentoring episodes through co-teaching courses, working on departmental policies, and sharing course plans and grant applications. Furthermore, encouragement of multiplex ties is beneficial for faculty whose areas of expertise are not redundant with those of their other departmental members. In this regard, our women engineering faculty participants discussed how their mentoring networks are situated within larger networks promoting complex and multifaceted relationships within and outside of their departments and broader academic communities. Despite our small sample size, we note differences in our participants' constructions of mentoring relationships and their network configurations that provide implications for further research and practical applications. We found that untenured and ethnic minority women faculty—in comparison to senior Caucasian women faculty--tend to seek mentoring more actively and their mentoring networks are usually expanded (i.e., these networks have more ties in general and more external ties) and more heterogeneous in terms of gender, race/ethnicity, seniority, and functions. In addition, senior faculty members seem to have more internal mentors within the department and/or the institution as a whole, whereas untenured faculty tend to have more external mentors. These trends in our data deserve require additional research to determine the nature and implications of these findings. As an exploratory study, our analysis provides a multidimensional snapshot of women engineering faculty's everyday mentoring experiences. Triangulated with interdisciplinary research, our findings are consistent with those from studies about mentoring in corporate settings[24,25,35] and with the relatively few non-network studies about women and underrepresented minority faculty in academe[1,8,32,34].

The main limitation of our study is that our mentoring network data have been derived from interviews. Although highly suggestive and rich, these data do not enable us to conduct the more sophisticated network mapping or statistical analyses that quantitative data would provide. However, our exploratory study is suggestive of future research possibilities. Future investigations could use questionnaires to collect network data for women faculty's mentoring networks as well as on these women's larger professional networks to contextualize women's mentoring experiences. Network analysis based on a larger sample size would provide correlations between mentoring characteristics and faculty success. This research also could study how mentors and mentees use multiple communication channels, such as social network sites and face-to-face meetings at professional conferences and workshops, in their mentoring networks over time and with what outcomes.

In addition to theoretical implications, our findings also suggest several practical applications, particularly for the development of mentoring programs in higher education. First, mentoring relationships are enhanced through processes of mutual agreement for mentor and mentee participation and opportunities for faculty members to get to know each other before

being formally assigned mentorship roles. In addition, formal mentoring programs need standard policies but should not be obligated to fulfill a "one-size-fit-all" set of procedures. How such programs and policies might be modified to suit particular mentorship partners within specific institutional venues would benefit from continuous feedback and improvements. Third, departments, colleges, and universities should foster cultures of mentoring that embrace collaboration, growth, inclusion, and co-learning. Faculty would benefit from more and varied network opportunities to engage in conversations and relationship building. Fourth, few faculty are trained to be effective mentors and mentees. Training is needed to educate faculty members about mentoring. Reward structures should recognize the time and effort required for effective mentoring. As role models and mentors for others, administrators and senior faculty members should take the lead in learning mentoring theories and promoting mentoring. Moreover, mentees should be encouraged to engage in mentoring networks whereby they construct collaborative and diverse mentoring partnerships to address specific areas of faculty activity, such as research, teaching, working towards tenure, and striking a balance between work and life.[40]

In closing, our study explores women engineering faculty's construction of mentoring relationships and their configurations. Through inductive and ego-centric network analyses, we found that dissatisfactions with formal mentoring systems can be mitigated by participants' constructions of viable networking relationships not bounded by department, school, or university and ranging from formal through informal and episodic or spontaneous mentoring forms. Women engineering faculty's network configurations were multiplex and heterogeneous.

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Table 1

A List of Participants

Pseudonym	Ranking
Berta	Assoc. Professor
Ellie	Professor
Zoe	Assoc. Professor
Yolanda	Assoc. Professor
Rachel	Professor
Nakala	Asst. Professor
Maria	Assoc. Professor

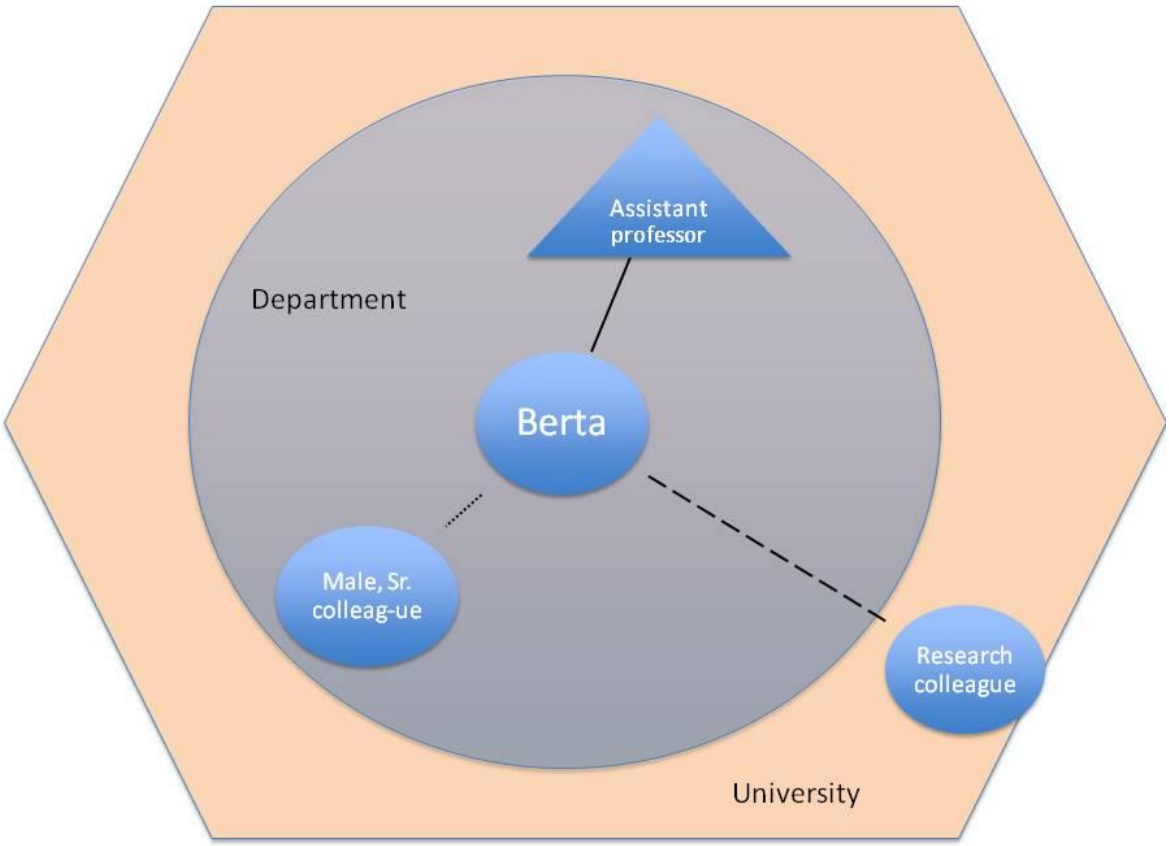

Figure 1. Berta's Mentoring Network

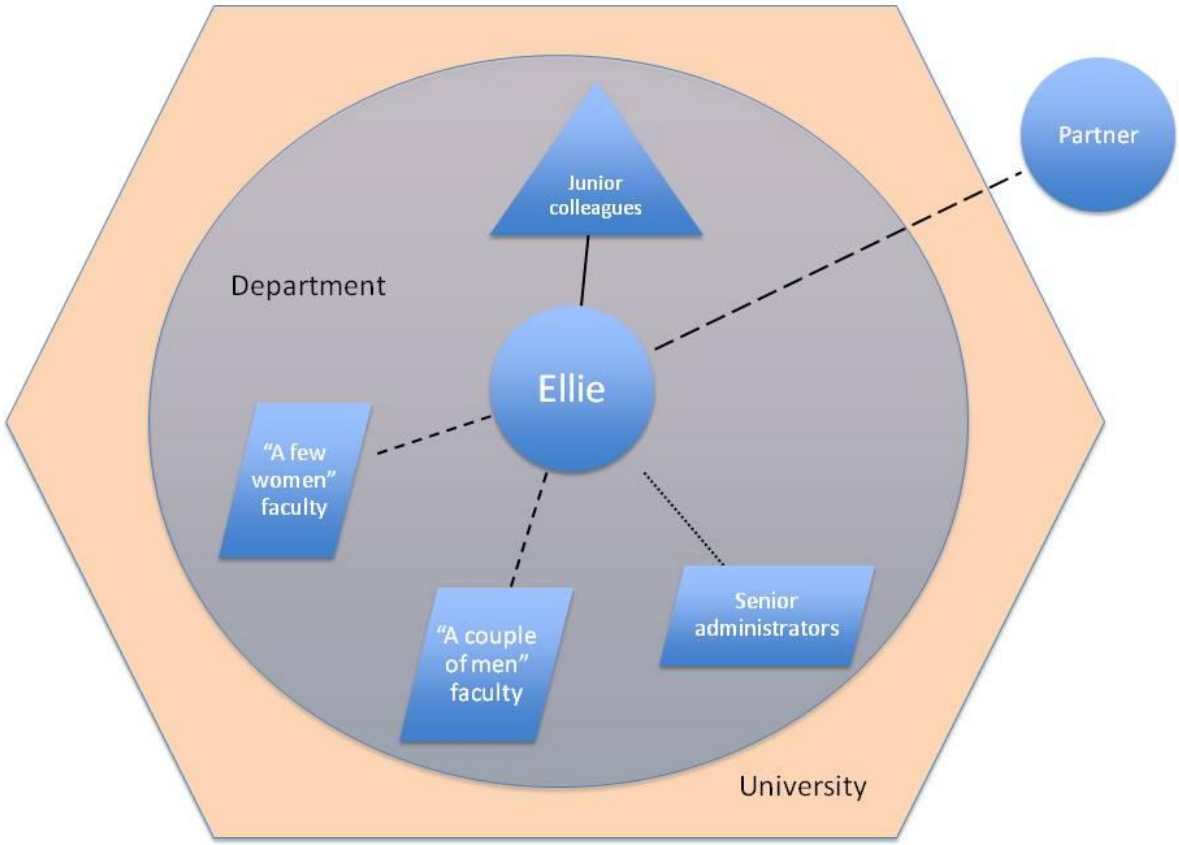

Figure 2. Ellie's Mentoring Network

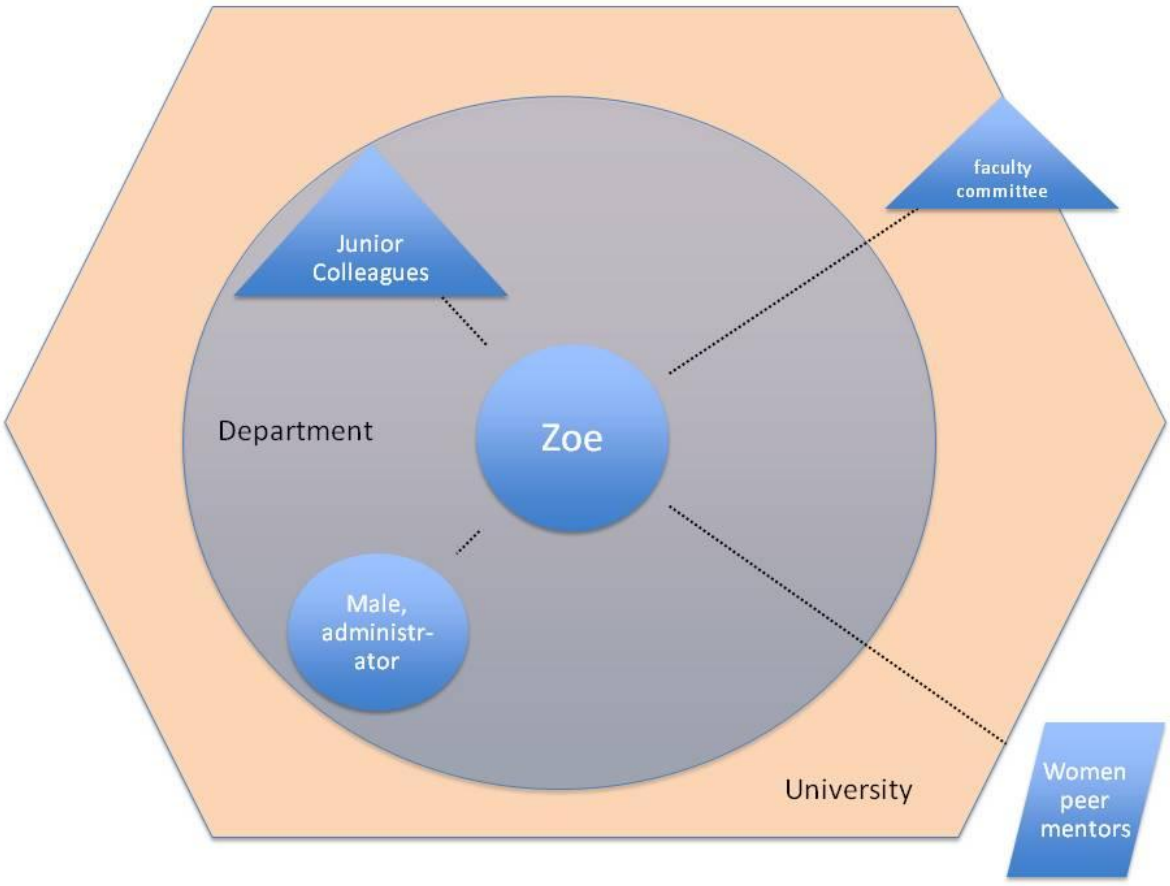

Figure 3. Zoe's Mentoring Network

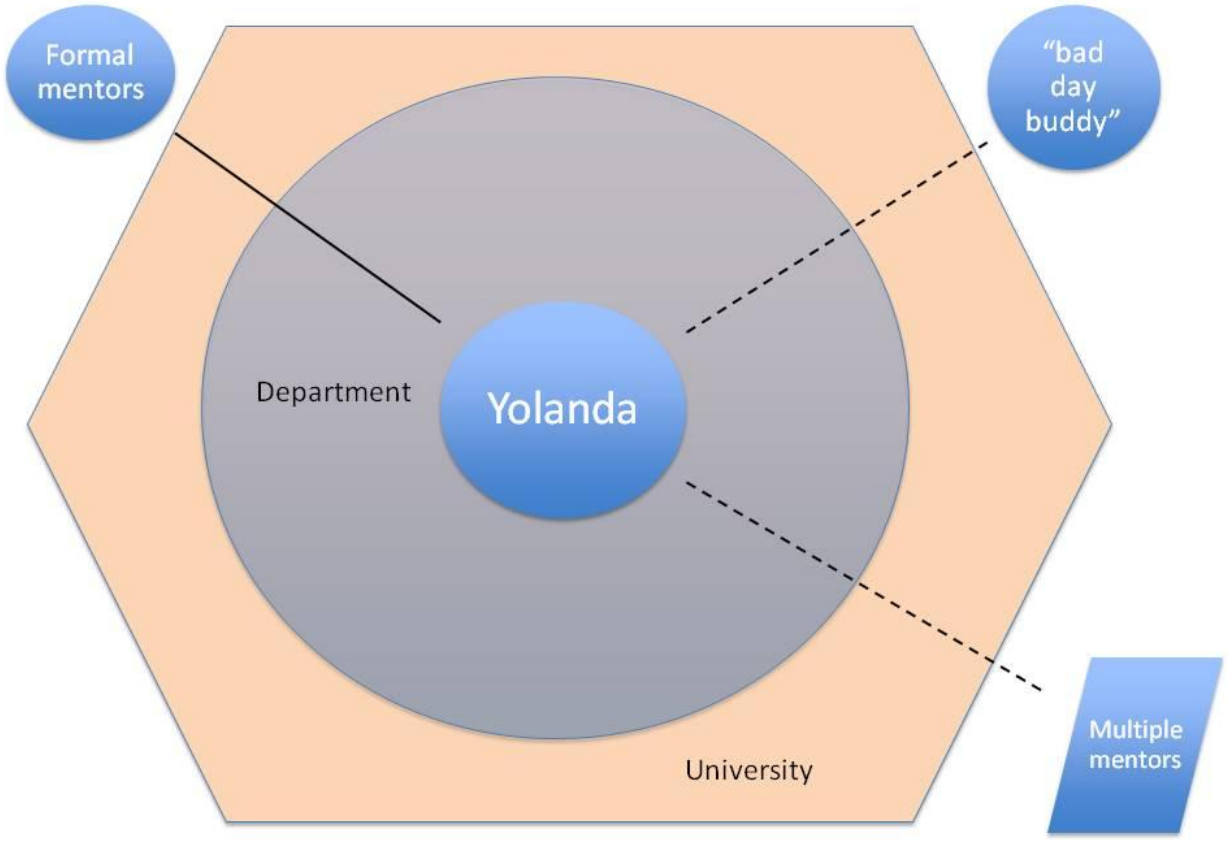

Figure 4. Yolanda's Mentoring Network

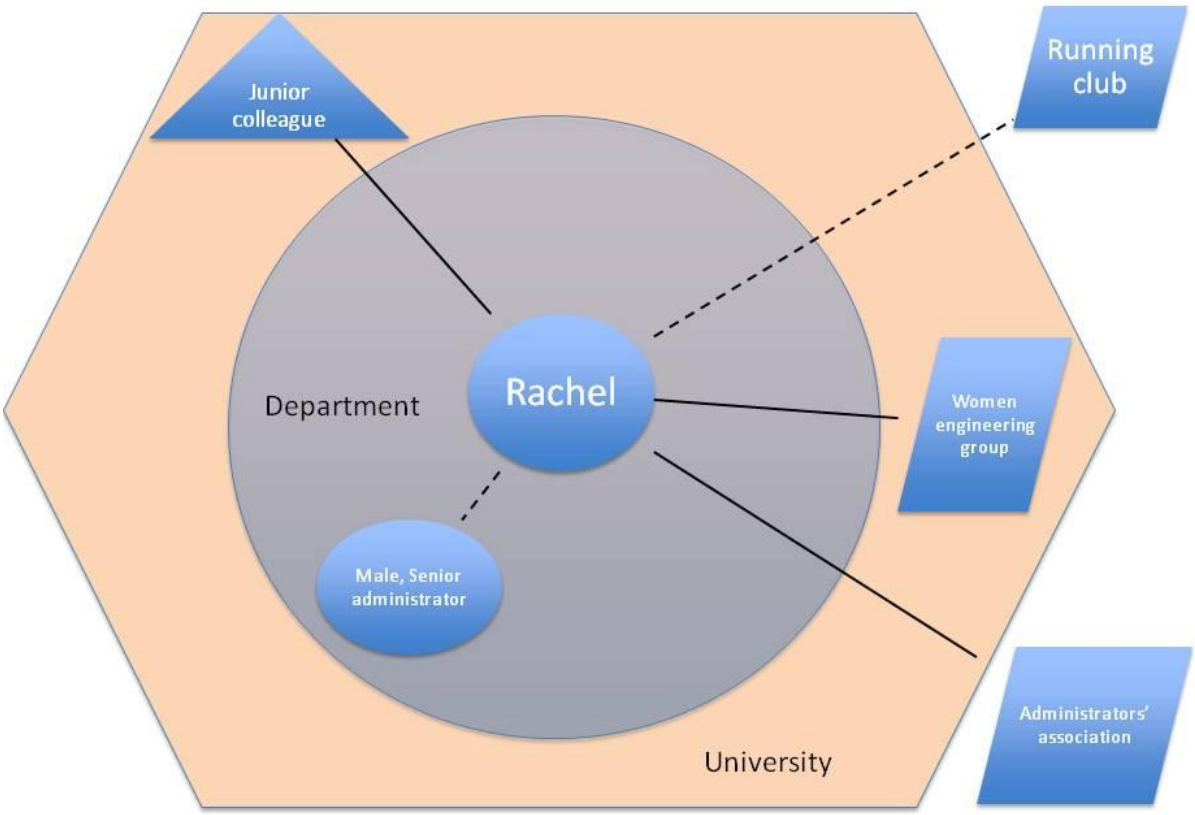

Figure 5. Rachel's Mentoring Network

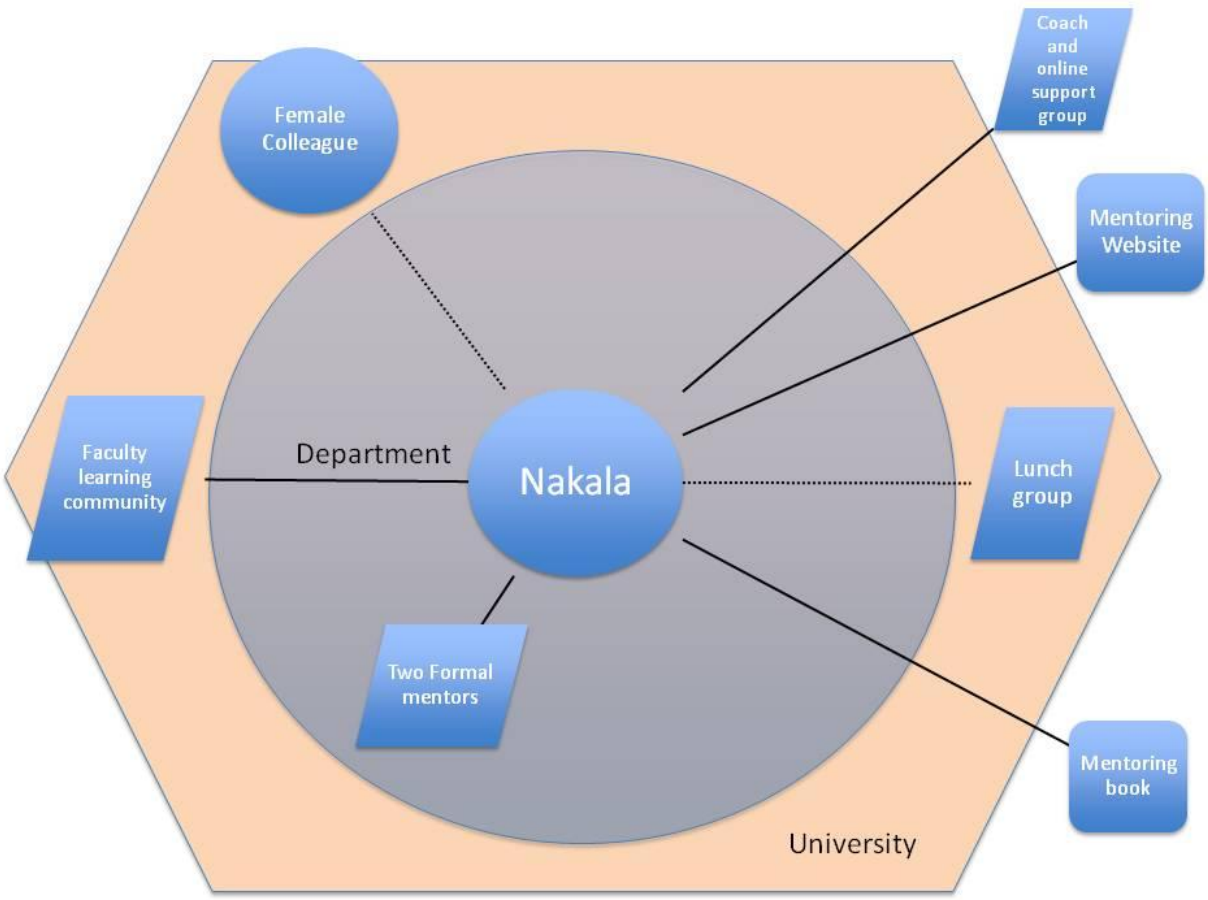

Figure 6. Nakala's Mentoring Network

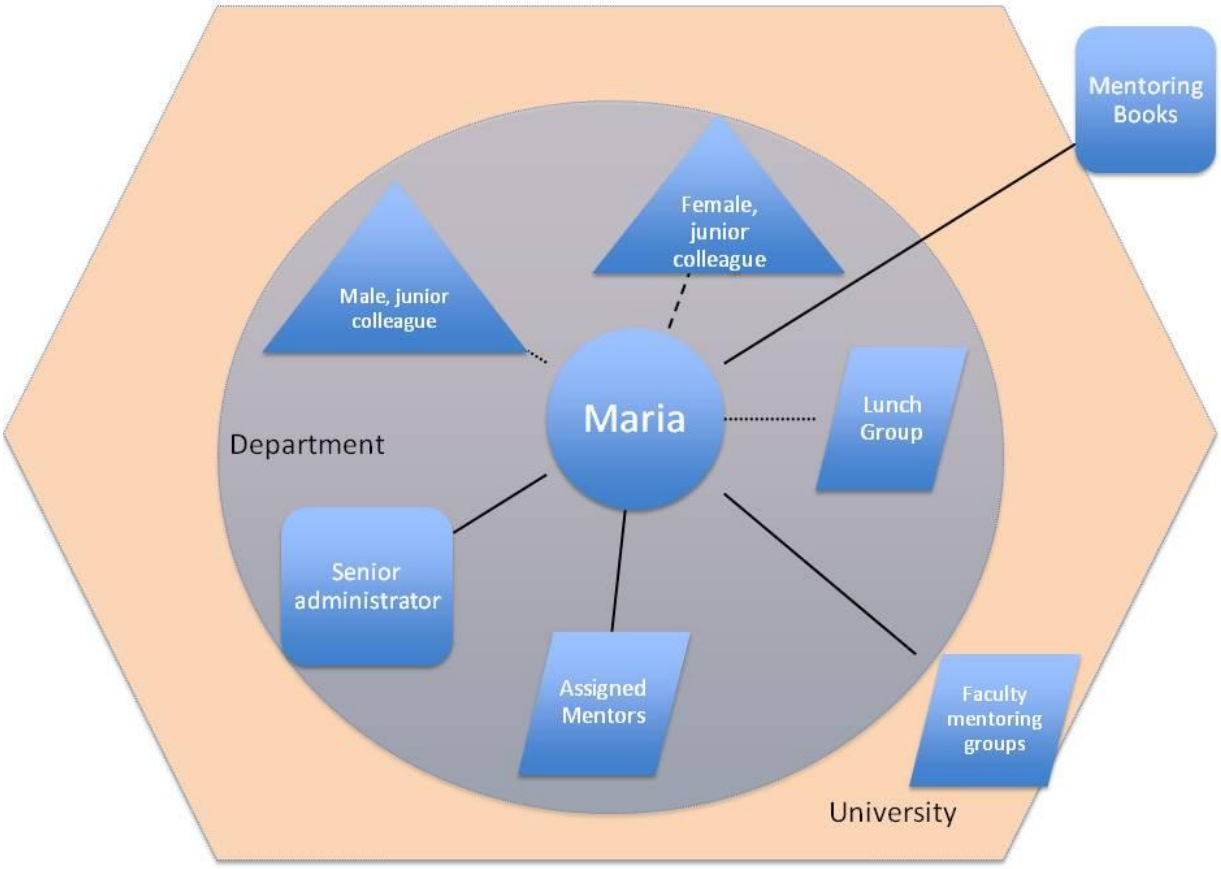

Figure 7. Maria's Mentoring Network

Appendix

Faculty Mentoring Interview Guide

Introduction & Personal information

1. Background information
2. Work history at Purdue University

Traditional mentoring experiences (formal and informal)

1. Do you have a **formal/informal** faculty mentor/mentee presently?

If yes

a. What do you mean by "formal"/"informal"?
b. Please describe the process that established your mentoring relationship.
c. Tell us about your strategies in maintaining the mentoring relationship
d. How does your relationship evolve?
e. Do you invest a lot in this faculty mentoring relationship? Why? How?
f. Overall are you satisfied with you mentoring relationship? Why or why not?
g. What are the challenges in establishing and maintaining meaningful mentoring relationship?
h. What do you enjoy most/least in the mentoring relationship?

If no

a. What are the reasons that you don't have a faculty mentor/mentee?
b. What are the advantages/ disadvantages of not having an assigned faculty mentor to your research, teaching, and service?
c. Who do you consult to receive career advice?
d. What are the challenges in establishing and maintaining meaningful mentoring relationship?

2. How would you compare the formal and informal instances of the mentoring?
3. Do you think having formal mentoring relationship is critical to faculty development, why?
4. Do you think having informal mentoring relationship is critical to faculty development, why?

Episodic Mentoring

1. What are the memorable advices you have received? Please describe the instances when you receive them.
2. Who would you consult when you have questions about work/life?
3. How often do you receive advice from colleagues? How did you use that advice?

Definition and Evaluation

1. What is your definition of the mentor/mentee/mentoring relationship?
2. What are some characteristics/skill sets of a good mentor/mentee in your opinion?
3. What do you think about the current faculty mentoring program in the CoE?
4. In your opinion, what goals should the current faculty mentoring program achieve?
5. What do you see as gap in the current mentoring programs to facilitate faculty development?
6. If you could design the ideal mentoring program for faculty in STEM disciplines, what would it include, how would it function/ operate, and how would it reflect the needs of the discipline? And why?

Ending: Anything else you'd like to talk about regarding faculty mentoring.