Peer Mentoring of Undergraduate Women in Engineering as a Mechanism for Leadership Development

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Abstract

Peer mentoring has been shown to be an effective means of improving the retention of women in engineering, but few studies have explored the impact of participation on the development of the leadership abilities of undergraduate women. Transitioning to a leadership mentality as a peer mentor has the potential to foster self-efficacy in science, technology, engineering, and mathematics (STEM) and socially stable academic relationships that may be replicated in post-graduate study and/or the workplace. This one-year study explored the experiences of junior and senior female students in STEM majors (N=11) serving as mentors to first-year students in the Women in Science and Engineering Honors Program (WISE) at Stony Brook University, a large research university in the Northeast U.S. The participants had also experienced mentoring by upperclassmen during their first year at the university. The conceptual framework incorporated factors related to self-efficacy and growth, communal agency, and leadership development. Qualitative data were collected through surveys and interviews with juniors and seniors. Many women expressed how rewarded they felt by their experiences with the first-year students, and they recognized the impacts of their work on the academic lives of their mentees. They viewed their mentees as more proficient in time management, work-life balance, and establishing effective social support structures. The mentors reported feeling confident in their leadership abilities and recognized the importance of supporting women as underrepresented participants in their university-based STEM community. They felt a personal responsibility to share their insights as academically and socially integrated upperclassmen. Findings suggest that mentoring programs should leverage the skills and achievements of peer mentors while enhancing their leadership transitions through the development of the self-determination of their mentees.

Introduction

Gender disparities in participation in engineering have been persistent in the U.S. for many years. Although the number of bachelor's degrees in engineering gradually increased by about 30% from 2000 to 2012, the actual number of degrees awarded to women has remained nearly constant (Figure 1). In light of the increase in overall engineering degrees, this translates to a continuing decline in the number of women receiving engineering degrees from about 16% in 2000 to about 13.5% in 2012 [1].
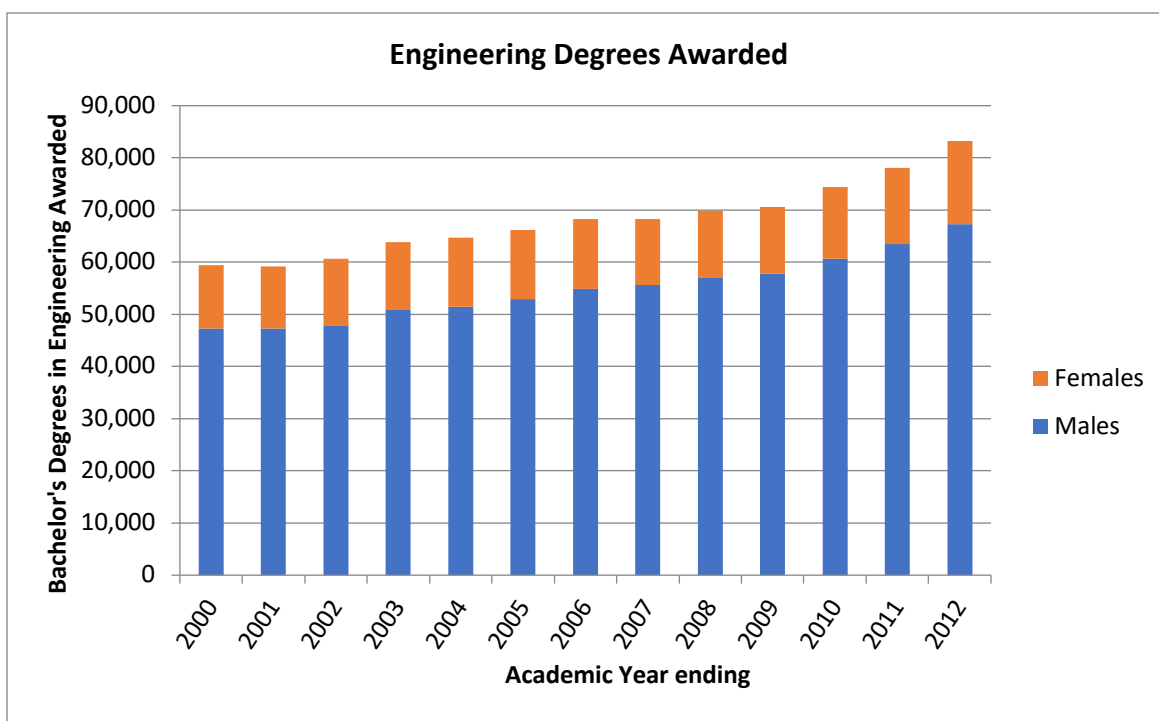
Figure 1. Bachelor's degrees awarded in engineering by gender, 2000-12 [1].

All students in undergraduate engineering programs have high rates of attrition, especially in the first two years when they have taken few, if any, engineering classes [2]. After completing threshold courses in college engineering majors, 77% of women and 82% of men were retained from 1982-1993 [3]. After the threshold courses, but before the degree, 65% of women and 80.0% of men were retained. This gender disparity widened for students completing engineering bachelor's degrees, with 62% of men and just 42% of women graduating [3]. This suggests the need for more targeted interventions to improve the retention of women in engineering and other STEM disciplines.

Peer mentoring. Peer mentoring has often been cited as an effective strategy for improving the retention of women and other traditionally underrepresented students. In a review of women graduate school engineers in the WISE-FPP (Women in Science and Engineering Future Professionals Program) at Syracuse University, researchers found that the interaction of women engineers sharing similar types of experiences was the most beneficial type of mentoring activity offered [4]. The informal activities provided through dinners, coffee chats, and post-lecture receptions offered graduate students the opportunity to discuss their shared experiences and relieve many of the feelings of isolation [4].

In determining the efficacy of a mentoring program at Washington State University, researchers compared the retention rates for female engineering students which stood at roughly 25% during the years prior to the start of a mentoring program. Since the mentoring program's inception, the rate of retention for female engineering students climbed steadily to about 50% [5]. While the authors acknowledged that mentoring alone does not solve all retention problems, it facilitated

the confidence to pursue engineering, resulting in greater retention rates [5]. A similar mentoring model examined attempts to build community and break down hierarchies in the engineering education community through monthly meetings, goal setting, and academic feedback [6]. Participants were surveyed at the end of the year regarding the associated value of the program and their individual identity development. The study concluded that most participants found peer mentoring to be useful in creating a nurturing, encouraging environment, with little personal costs by way of effort and time, and participation in the program reduced self-doubt through shared experiences in a like-minded community [6].

STEM leadership development. By serving as an undergraduate peer mentor for those who are newly enrolled in STEM programs, young women have the opportunity to lead their mentees through challenging academic and social transitions. Research on STEM leadership development has been somewhat limited although some researchers have identified ways in which leadership qualities are facilitated for mentors in STEM disciplines. Leadership in STEM educational contexts has been characterized by those who consciously connect the social and the academic, as well as the past experiences and future objectives; Beattie stated that this is "… a view of leadership that is inclusive, connected, and collaborative" [7, p. 201]. Other researchers have identified leadership as the ability to influence others through interpersonal skills, advocacy, and facilitating institutional networks [8]. Generative leadership is characterized by reciprocal mentoring relationships, where both mentors and mentees are building competence and enhancing problem solving skills [9].

Research questions. This research study examined the impacts of the mentoring experience on junior and senior STEM students serving as peer mentors to first-year female students. To build upon prior work in the STEM mentoring field, the overarching research questions were: How did service as a peer mentor to first year female students impact the women serving in these roles? How did mentoring service facilitate leadership development among junior and senior mentors?

Conceptual Framework

Much of what is known about self-efficacy and its role in persistence of behavior is based upon the research of Bandura, who distinguished between both efficacy expectations and outcome expectations [10]. An efficacy expectation is the personal belief that one can execute the behavior needed to produce an outcome, whereas an outcome expectation is the personal belief that that specific behavior will lead to the desired outcome. Performance accomplishment, vicarious experiences, social persuasion, and psychological state are key components of efficacy expectations. Only through confidence that personal mastery of tasks is possible can students adequately cope with the fear and reality of occasional failure. Seeing challenges mastered by others can give students the vicarious experience that performance improvement is possible. While social persuasion induces a weaker form of self-efficacy expectations, since it does not come from one's own personal accomplishment, social persuasion in the form of a supportive group can make a difference [10].

Bandura [11] expanded on these ideas when discussing perceived self-efficacy. It is not just situations in which students experience success or failure, but the perception of situations which

may or may not result in success. Since most behaviors are purposeful in nature, the anticipation of moving into unknown scenarios can elicit anxiety and self-doubt. Students who are capable of visualizing and modeling these particular scenarios in anticipation of their participation can often reduce the stress and anxiety tied to unknown situations [11].

Lent et al. [12] posited that self-efficacy, outcome expectations, and personal goals are the three basic tenets of career development. Self-efficacy is seen as an ever-changing set of self-beliefs regarding specific performance capabilities that results from the complex interplay of personal behaviors, interactions with other people, and environmental factors. Although the authors agreed with Bandura [10] that performance accomplishments, vicarious learning, social persuasion, and psychological state influence and alter self-efficacy beliefs, they believed that personal performance accomplishments are the greatest contributors to self-efficacy [12]. Peña-Calvo, Inda-Caro, Rodríguez-Menéndez, and Fernández-García [13] utilized Lent's work [12] to examine the perceptions of barriers and supports in a study of 811 sophomore university students in Spain. The researchers found that relative to other STEM students, engineering students identified greater issues between teachers and students, such as lack of professional role models, lack of encouragement to accomplish tasks, and gender bias, particularly against females, which hindered achievement of intended goals. The engineering students also identified fewer teaching staff supports, such as mentoring networks that encouraged student goals as well as reassurance that students were capable of mastering the material to be successful in engineering. Interestingly, the study found that while women studying engineering acknowledged more teaching staff barriers than women in other STEM fields, including lack of role models and lack of connection to faculty, they noticed fewer peer barriers including less competition between classmates and an increased ability to establish relationships with classmates [13]. This is consistent with previous work that suggested women in pre-college STEM environments increase self-efficacy in supportive contexts where they had opportunities for design autonomy, practice in developing real-world technological solutions, and exposure to working engineers [14], [15].

Research Design

Context. The research took place at Stony Brook University, located in the Northeast U.S. with an undergraduate enrollment of approximately 17,000 students. The undergraduate population was 54% male and 46% female. This university hosts the WISE Honors Program to encourage and support women in their pursuit of a degree in STEM fields. Admission to WISE for incoming college students is highly competitive and applicants must show both ability and interest in science, mathematics, and/or engineering. The WISE Honors Program employs peer mentoring as a way to help first year students adjust and maintain their persistence and interest in STEM.

Participants in this study included female undergraduate students acting as mentors in the WISE Honors Program. Of the approximately 200 women enrolled in the WISE Program as of 2016-17, a subset of female juniors and seniors acting as mentors were recruited to participate in the study ($N = 11$). The mentoring program within WISE was a voluntary experience where approximately 20 juniors and seniors worked with five or six first year female students in WISE;

the mentors received a stipend for their efforts. They met weekly for six hours to informally discuss social and academic issues, work on course assignments, and develop a supportive network. The participation of the first-year students was mandatory. The 11 mentors were surveyed and/or interviewed in spring and fall of 2017.

Design and methods. A phenomenological research design [16] was employed, whereby the common experiences of the subjects as undergraduate women mentors in STEM were explored, with a particular focus on the impact of mentoring on self-efficacy beliefs, personal growth, and leadership development. Common constructs were elicited to generate a new explanatory framework about practices to increase the retention of women in STEM and their satisfaction in their fields. The analysis of the qualitative data employed a thematic approach involving open, axial, selective, and thematic coding. In the first cycle, a priori coding [17] was performed based on a hypothesis that mentoring increases both self-efficacy beliefs and behavioral and intentional persistence in STEM. These a priori codes were drawn from broad categories found in the literature. The second phase was axial coding, whereby one category was chosen to be the center point of a theory and additional categories were identified to create a theoretical model [17]. Selective coding emerged from the creation of a theory from the relationships among all categories. Thematic coding elicited the larger themes that resulted from the data [16]. The interviews and surveys gave rise to the selective and thematic codes and these contributed to a new framework for examining how the mentoring experience contributes to the development of student leaders in STEM. Two researchers analyzed the transcripts and survey responses and achieved interrater reliability through extended discussion.

Results

The impacts of the WISE mentoring program on junior and senior mentors had both personal and social dimensions. In both cases, the women's experiences contributed to their growth and in many cases facilitated leadership qualities.

Personal growth of mentors and mentees. The mentors spoke at length regarding the personal benefits of their experiences. The women expressed personal satisfaction with being a mentor, and many described how rewarded they felt by their experiences with the first-year students. They recognized the impacts of their work, which provided a sense of gratification that they had positively influenced others. One mentor stated, "I absolutely love being a mentor. I get to share my advice and lessons I've learned. I love to feel wanted and trusted. I do feel I have had a good influence on my mentees." They often commented on recognizing the value of their work. Another student shared her primary reason for becoming a mentor, focusing on the tangible benefits her mentees would experience:

> So I think that my main priority becoming a mentor was that I could give a sense of support and serve as a resource to freshman girls who didn't really know where to start, or like as a mentor, I could try to help them get more acclimated and feel like they could have someone to turn to if they did encounter problems academically, socially or emotionally, mentally, etc.

Since the mentors had all been mentored themselves as first year students, they often discussed the continuing relationship with the women who had served in this role. This contributed to their self-efficacy in the role since they had personally experienced the same advantages. One student described the sense of camaraderie that she felt with her mentor and previous mentees:

> I'm finding the experience highly rewarding. I'm still friends with my mentor from three years ago and reach out to her for advice and previous mentees reach out to me often. The bonding has resulted in success that would not have happened without the program and community.

Mentoring was prioritized by many of the women since they recognized the sustained impact of their efforts. They often viewed themselves as aspirational role models for the first-year students with whom they interacted. One student contextualized the importance of her work in terms of facilitating the growth of others:

> I think that I really prioritize mentoring. I think that it's something very important to me because just reflecting on my past year of mentoring, it's been very rewarding in the fact that my mentees still turn to me from last year for help and they still want to hang out with me and I take comfort in the fact that maybe I didn't like hold their hand throughout the process, but I helped them grow.

The personal growth and satisfaction the mentors experienced was also expressed in terms of giving back to a program that had provided support for them as first year students, which was typically a chaotic time for them personally and academically. This sense of altruism and community was fostered by the tangible benefits they had received themselves early in their academic careers. One woman described how the community of mentors shared a common commitment to improving the lives of young women who preceded them in the program:

> I got to meet other women like younger than me too who I guess share the same passion of wanting to give back to WISE, wanting to give back to the community and freshman girls who encountered similar experiences as us.

Social benefits. The social benefits from serving as a mentor were apparent in terms of facilitating agency, expectancy, and work-life balance for the first-year mentees. The mentors often shared experiences whereby the first-year students needed assistance with institutional knowledge and procedural agency. That is, they needed support in figuring out university logistics, academic expectations for their majors, and how to choose academic course pathways to meet their goals. One mentor shared the need for some first-year students to get acclimated to rigorous course requirements, which was challenging for many:

> I love being a mentor. I love having the chance to try and help my girls with transitioning into college and getting adjusted to the very intense coursework of BME [biomedical engineering], while also supporting them emotionally.

Some mentors spoke of their self-doubts when choosing a major and persisting in STEM, and their struggles with accepting ambiguity regarding career pathways. For many of the young women, their college experiences were a journey of self-discovery, and the uncertainties that

characterized that time were sometimes sources of tension. They saw these same self-doubts in their mentees and discussed ways in which they helped them adjust. As one mentor stated:

> I think one of the things that I've taught them is that even though there's so much pressure to know exactly what you want, it's okay to explore or discover who you are. I think that's really what college is about. If anything, what I try to do is expand their world view and not let them be limited by one path, but to let them allow themselves to explore what they want, what they desire out of themselves and once they find something that they're passionate about like I have, I want to show them by example that pursue it 110 percent.

The mentors also worked with the mentees in establishing work-life balance. This seemed to be of particular importance for women in STEM due to the many academic pressures and time constraints. One mentor concurred by stating, "I think work social balance is something that all college students have to learn to juggle, but especially WISE women, especially women in STEM. It can be particularly difficult." According to the mentors, the first-year students desired academic success and space in their lives for socialization and networking. They often sought advice from mentors on how to achieve more balance in their lives. One mentor stated that success "… takes determination and consistency and often you have to put like the immediate gratification like fun things on the back burner in order to succeed academically in STEM." By helping their mentees find mechanisms to balance their priorities, the mentors felt the first-year students were more likely to maintain their satisfaction and persistence.

One final social benefit of serving as mentors was the development of self-identification as a leader. Many mentors shared that they viewed themselves as trusted peers with a responsibility to develop the first-year students they mentored. Some saw this specifically as a characteristic of leadership, for example, one mentor stated, "I think that a leader is someone who demonstrates by example and a leader is a role model, and I try to be a role model to my mentees, but not limited to my mentees." By making decisions and providing guidance to younger students in STEM, they were fostering the next generation of talent to be successful both socially and academically.

Discussion and Conclusions

The mentors frequently referenced personal growth as well as social good as tangible benefits of their participation. They specifically felt personal gratification from working with others, which led to a sense of collective agency from their interactions with their mentees as well as fellow mentors. They experienced intellectual and social resonance with like-minded women who shared their passion and drive to succeed in rigorous STEM disciplines. They also noted the societal benefits of their mentoring work. Their mentees often need counseling on the logistics of the institution, for example, registration, finding research opportunities, and interacting with faculty. The first-year students experienced ambiguity in their academic pathways and were often seeking a personal fit that matched their career expectancies and personal values, consistent with psychosocial research in behavioral and intentional persistence [18]-[20]. The mentors were pleased with their effectiveness in helping the first-year students tolerate the uncertainties of

developing work-life balance in their undergraduate experiences. By communicating expectancies of known situations, the mentees were supported and strengthened in their sense of belonging in the STEM community.

Transitioning to leadership. The shared experiences of the junior and senior mentors were insightful in other ways. Their work was also personally rewarding in terms of their transitioning to leadership roles within the WISE community. Research has shown that women in leadership positions have the potential to be transformative through their work in achieving equity in STEM, and this often occurs through acting in roles that have "aspirational status" relative to mentees [21]. By serving as role models to first year students who were sometimes experiencing social and academic anxiety, the mentors encouraged their peers and built their sense of STEM competence. Networking opportunities reduced isolation and improved self-efficacy and social interconnectedness; this was similar to findings from previous research on the importance of academic integration and mentoring programs for women in STEM [20], [22], [23]. However, this research builds upon prior work by demonstrating that the mentors' efforts in motivating novice students and facilitating support and resilience were key aspects of effective leadership. They recognized the many benefits of their interactions, which motivated them to continue their activist roles in a communal network of highly accomplished young scholars. The personal and social constructs and their contribution to leadership development are summarized in a new explanatory framework in Figure 2.
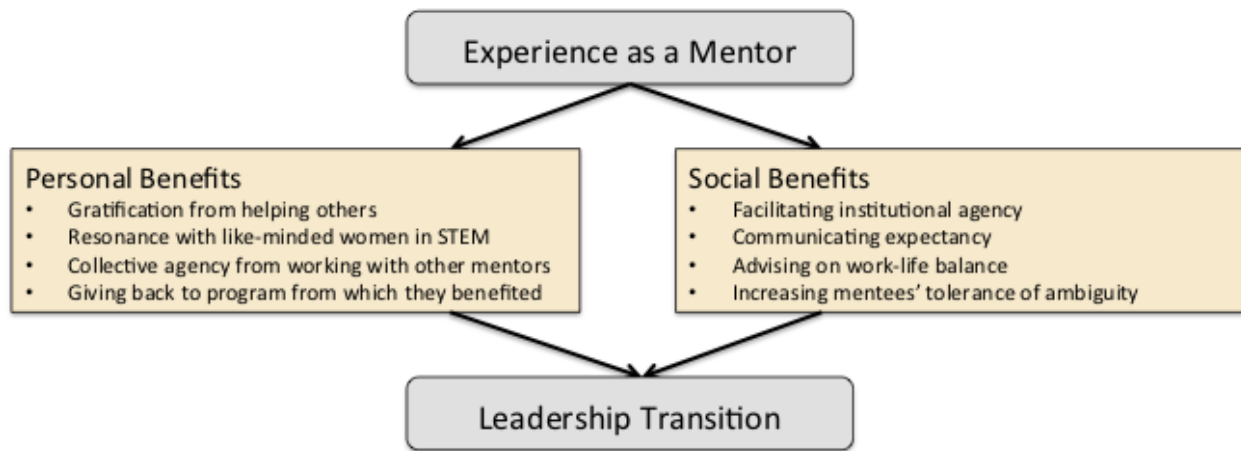

Figure 2. Explanatory framework for leadership transition.

Limitations. There are several limitations inherent in the research design. The sample size of mentors was small and for most subjects, data were collected at a single point during their mentoring service. Although these survey and interview responses were insightful, a repeated measures approach may have identified trends and shifts in perspectives over time. Data were self-reported from junior and senior mentors, yet triangulation with the mentees' perspectives would strengthen validity of interpretation.

Future research. This preliminary research will be continued in several ways. First, the mentors will be followed over several years to measure long-term impacts of WISE mentoring service. Secondly, quantitative data will be collected to compare specific leadership constructs both

within WISE groups and between WISE and non-WISE control groups. Finally, future work will triangulate findings from mentors with matched data from program mentees. This research and future work will contribute to expanding the knowledge base of the role of mentoring in developing future women leaders in STEM in higher education and the workplace.

Acknowledgments

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