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Catalysts of Women’s Success in Academic STEM: A Feminist Poststructural Discourse Analysis

Dianna R. Dekelaita-Mullet
Navajo Technical University

Anne N. Rinn
University of North Texas

Todd Kettler
Baylor University

Catalysts of Women's Success in Academic STEM: A Feminist Poststructural Discourse Analysis

By Dianna R. Dekelaita-Mullet[1], Anne N. Rinn[2], Todd Kettler[3]

Abstract

This qualitative study seeks understand the phenomena that activate women's success in STEM disciplines where women's representation has not yet attained critical mass. A poststructuralist emphasis on complexity and changing nature of power relations offers a framework that illuminates the ways in which elite academic women navigate social inequalities, hierarchies of power, and non-democratic practices. Feminist poststructural discourse analysis (FPDA) draws from the women's experiences to better understand their complex, shifting positions. Eight female tenured full professors of STEM at research-focused universities in the United States participated in the study. Data sources were in-depth semi-structured interviews, a demographic survey, and curricula vitae. Findings will help shape programs and policies aimed at increasing female representation and promoting achievement at senior levels in academic STEM fields.

Keywords: Women, Science, STEM, Higher education, Poststructuralism, Discourse analysis

Introduction

Women science faculty contribute to the diversity and creativity of the scientific community in significant ways, particularly in fields regarded as consequential for national innovation (National Academy of Sciences, 2006). With the end of second-wave feminism in the early 1980s came the perception that the women's movement had succeeded in freeing women from oppression (Hopkins, 2002). Nevertheless, despite gains such as women's sexual and familial rights, equitable social attitudes toward gender roles, and laws establishing equality and prohibiting gender discrimination (Thornham, 2001; West & Curtis, 2006), very few women in science, technology, engineering, and mathematics (STEM) attain elite levels within the academic hierarchy. Women remain severely underrepresented among senior faculty positions in STEM; they simply do not advance to high rank at the same rate they enter STEM fields. The purpose of this inquiry is to describe and understand factors that catalyze the success of elite female scholars in science, technology, engineering and mathematics (STEM), particularly in disciplines where women's representation has not yet attained a critical mass. In this study, "STEM" is limited to

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[1] Dianna R. Dekelaita-Mullet, PhD is Assistant Professor of Psychology at Navajo Technical University, where she also serves as Program Advisor for Counselor Education and Head of the School of Arts and Humanities. She studies creativity and talent development in science and technology.
[2] Anne N. Rinn, PhD is Professor of Educational Psychology at the University of North Texas, where she also serves as Director of the Office for Giftedness, Talent Development, and Creativity. Her research focuses on the social, emotional, and psychosocial development of gifted and talented individuals.
[3] Todd Kettler, PhD is Associate Professor of Educational Psychology in the School of Education at Baylor University where he coordinates undergraduate and graduate programs in gifted and talented education. He studies critical thinking, creative thinking and gifted education.

disciplines where women's representation in the full professor rank has not yet reached a *critical mass*, or at least 15-20% representation (Etzkowitz, Kemelgor, & Uzzi, 2000): those disciplines include physical sciences (chemistry and physics; 15%), computer science (12%), engineering (8%), and mathematics (16%; NSF, 2017).

Although the proportion of women faculty in STEM is important, so are the ranks that women hold (Fox & Kline, 2016). While numbers of women in the sciences have grown considerably, women do not "rise to the top" at the same rates they enter STEM fields and remain vastly outnumbered by men at the highest positions in those fields (Hill, Corbett, & Rose, 2010). Women's rank of full professor is of particular concern because that senior rank holds vital decision-making authority in higher education (National Academy of Sciences, 2006). In academic careers with conventional milestones, a progressively smaller proportion of women advances to each subsequent milestone relative to their male colleagues (Etzkowitz et al., 2000). For instance, in 2015 42% of all tenured faculty were women (McFarland et al., 2017). The trend is especially conspicuous in academic STEM. For example, although 41.6% of doctoral degrees in science and engineering were awarded to women in 2014, women represented only 33.9% of faculty at doctorate-granting research universities classified as R1 or "very high research activity" ("The Carnegie Classification," n.d.). Representation among tenured and senior STEM faculty is yet smaller; in 2014, women held only 25.7% of tenured science and engineering positions at 4-year colleges and universities and represented 20.8% of full professors in science and engineering (National Science Foundation, 2017). In math-intensive STEM disciplines, women have not yet achieved critical mass in higher status positions (Richman et al., 2011): in 2013, women represented 16.2% of full professors in mathematics, 15.2% in physical sciences, 12.5% in computing, and 7.5% in engineering (National Science Foundation, 2017). Additionally, senior women are less likely than their male colleagues to hold faculty leadership positions such as endowed chairs, department chairs, or deans (Bilimoria, Joy, & Liang, 2008).

Elite levels in the academy are virtually devoid of women. Data on women's representation in the membership and governance structures of national science academies affiliated with the Global Network of Science Academies shows that at 12% overall, women's membership remained far below parity with men's (Ngila et al., 2017). Women members were represented to a greater degree in the humanities and social sciences (20%) than in the natural sciences and engineering, where women's membership remained well below 10%. Also conspicuous is gender imparity among recipients of prestigious international STEM awards. Of the 881 Nobel Laureates only 49, or 5.6% were women ("Nobel prize facts," 2017). Three women have received the Turing Award in computer science since its initiation in 1966 ("ACM Turing Award," 2017). In mathematics, the famed Fields Medal has been awarded to a woman once since its inception 80 years ago ("Fields Medal," 2017), and in 2019 the Abel Prize was awarded to a woman for the first time since its inception in 2002 ("Karen Uhlenbeck," 2019).

Numbers of Black, Latina, and Native American women in STEM are strikingly small. Data collected in 2007 from the top 100 science, engineering, and mathematics departments in the United States paint a bleak picture (Nelson, Brammer, & Rhoads, 2010): of 2,787 tenured chemistry faculty, eight were Black women, 13 were Latina women, and one woman was Native American. Of 3,335 tenured physics faculty, two were Black women, nine were Latina women, and none were Native American women. Among 4,303 tenured mathematics faculty, seven were Black women, 16 were Latina women, and none were Native American women. Women of color are virtually absent among senior STEM faculty in the top 100 departments: in 2007, there were no Native American women full professors of chemistry, physics, nor mathematics; there were only three Black women full professors in mathematics and none in chemistry nor physics; and four Latina women full professors in chemistry, one in Physics, and six in mathematics and statistics (Nelson et al., 2010).

Women successful in STEM research are profoundly resilient and show phenomenal persistence (Tirri & Koro-Ljungberg, 2002) despite hardships and obstacles such as isolation, failures of others to recognize their potential, and lack of social support from male peers (Charleston, George, Jackson, Berhanu, & Amechi, 2014). Women come to accept persistence as a necessary "part of the package" (Kachchaf et al., 2015, p. 185) in an academic STEM career. A woman's identity as a scientist may contribute to persistence in STEM. A well-developed identity as a woman scientist enables a woman to reinvent the notion of "scientist" in ways that resist masculine gender norms that pervade STEM. For instance, when confronted with barriers in their STEM work, some women responded by expanding their STEM identities to include their altruistic values (Hodari et al., 2016). Further, women who accommodated their outsider positionality were able to use their dual perspectives to conceive of possibilities that transcended mainstream thought (Pololi & Jones, 2010). Ideally, recognition of a woman's STEM identity by powerful others serves as an avenue for reconstructing gender norms and feminizing science.

Resources within institutional environments such as funding, reduced teaching loads, lab space, and support staff help women advance in their academic careers (National Research Council, 2010). Collegial, positive departmental climates are especially important for women (Holmes, Jackson, & Stoiko, 2016), and women are more successful in collegial environments that provide psychological safety to take risks for innovative work (Etzkowitz et al., 2000). STEM women acknowledge the role of mentoring in supporting their career goals, bringing meaning to their work, and helping them navigate the challenges of academic work in effective and personally fulfilling ways (Buzzanell et al., 2015), and peer support groups represent a means of meaningful, long-term support for women marginalized in their disciplines (Greene, Stockard, Lewis, & Richmond, 2010; Stockard & Lewis, 2013). For many women, participation in a support group represents a community that before had been unavailable, increases their sense of belonging in their discipline (Thomas et al., 2015), and enhances confidence in their abilities to negotiate challenges within their disciplines (Greene et al., 2010; Stockard & Lewis, 2013).

Method

Significance

The study aims to identify factors that activate women's success in STEM disciplines where women's representation has not yet attained critical mass. The study also aims to raise awareness of the need for continued work toward gender equity in higher education. The following research question guided the inquiry: To what factors do high ranking academic women who launched careers after the end of second-wave feminism attribute their success in highly male-dominated STEM disciplines?

Regrettably, a dearth of empirical research exists to explain why so few women persist where so many other capable women fail to reach their potential (Mullet, Rinn, & Kettler, 2017). The current study brings new perspectives to this understudied topic and adds to the literature in several ways. First, existing research has tended to focus on barriers, obstacles, or challenges that lead to women's attrition. Instead, the current study takes a positive perspective and explores women's strengths, actions, external supports and other factors that foster their success in STEM. Second, few studies on this topic have employed feminist research methods (Mullet et al., in press) and feminist poststructural methods have yet to be used widely in feminist educational research (Baxter, 2002). The qualitative, feminist and poststructuralist approach of the current study departs from prior approaches, bringing a new perspective to previous work by focusing on the women's unique, situated experiences and shifting positions of power within the context of male-dominated STEM. Finally, to our knowledge there exist no empirical studies of contemporary elite women in academic STEM; the sample of contemporary high-ranking academic women in this study helps fill that gap in the literature.

Theoretical Framework

Poststructural feminism challenges the essentialist notion that women constitute a single, static category of identity and instead frames "woman" as emergent and constantly shifting, multifaceted, and constructed within competing discourses (Butler, 1990). With its emphasis on complexity and the shifting nature of power relations, poststructural feminism provides a framework for understanding the ways in which women simultaneously engage in resistance and are subjected to power (St. Pierre, 2000). Although they share the same biological sex and professional context, STEM women vary in many ways including educational background, race, nationality, gender identity, relationship status and intersections of any of those characteristics. Poststructural feminism highlights multiple positions in women's lives and identities and explores how those positions are perceived and shaped by the women themselves and by others (Frost & Elichaoff, 2014). For instance, as subjects marginalized by dominant male discourse, high-ranking women faculty in STEM hold an advantaged position—outsider in a discourse—that embodies a richer, more complete perspective that includes both their own experiences and those of the dominant ideologies to which they are subjugated (Rosser, 2000).

Participants and Data

Participants in the study (Table 1) were purposively sampled to select elite female STEM faculty members holding full professorships in STEM disciplines. Potential participants were recruited from public and private doctoral granting institutions classified as R1 ("highest research activity") by the Carnegie Classification of Institutions of Higher Education (n.d.). Each institution with a public online faculty directory was searched for female, tenured professors in physics, chemistry, computer science and engineering, or mathematics. Forty potential participants were emailed invitations to participate. Initially, 23 women responded and were asked to complete an online demographic survey (Appendix A) and provide a curriculum vitae. Eight women agreed to participate. The women are referred to by pseudonym. Data items included in-depth interviews, demographic survey responses, and curricula vitae. Curricula vitae were used to evaluate the timing of major events along women's career paths (see Table 1). In-depth interviews were audio recorded and followed the interview guide outlined in Appendix B. Recordings were checked for identifying information (none was found) then transcribed verbatim by a professional transcription service.

Data Analysis Procedures

Multiple case study methodology provides a "holistic understanding of a problem, issue, or phenomenon within its social context" (Hesse-Biber & Leavy, 2011, p. 256). Case study methodology avoids essentialist, context-free analyses that can be harmful to disempowered groups (Hesse-Biber & Leavy, 2011) and is suited to investigating intriguing people in depth (Saldaña, 2015). The analysis took place in two stages. The first stage, thematic analysis, identified recurring themes that represented the factors that catalyzed the women's success in their STEM careers. The second stage, feminist poststructural discourse analysis, aimed to reveal the women's multiple, competing positions within their masculinized academic contexts.

Thematic Analysis

Themes recurring across interview transcripts were identified using thematic analysis, a qualitative data reduction method for identifying patterns within data (Braun & Clarke, 2006). To generate codes, the investigator used a coding procedure similar to that outlined by Leech and Onwuegbuzie (2011). The initial codes were reduced to a smaller set of concise themes. A theme "captures something important about the data in relation to the research questions" (Braun & Clarke, 2006, p. 82). An iterative process of grouping the nodes based on meaning, combining similar nodes, and eliminating nodes reduced the number of nodes to 15, comprising six major themes and nine subthemes (Table 2).

Feminist Poststructuralist Discourse Analysis (FPDA)

FPDA is a feminist approach to analysing ways in which speakers negotiate their identities, relationships and positions in their worlds. The key functions of FPDA are to identify key gender discourses within specific contexts and to reveal ways in which competing discourses position speakers as powerful, powerless, or a combination of the two (Baxter, 2003). FPDA highlights women's strengths within interactions while also considering reactionary effects of institutional discourses on women's experiences (Baxter, 2003). The FPDA analysis followed guidelines set forth by Baxter (2008). The first stage, denotative microanalysis made a close, detailed, but non-evaluative description of speakers' verbal and nonverbal language. The second state, connotative analysis interpreted selected data in terms of participants' shifting positions of power amid competing discourses.

Results

Thematic Findings

Thematic analysis produced five major recurring themes that signify broad factors that catalyzed the women's success. The themes are described below.

The women shared many traits, motivations and approaches to thinking and working. The women possessed a high level of openness including willingness to take risks, nonconformity, multiple interests and abilities and receptivity to diversity. The women were oriented toward communal goals and demonstrated care and respect for others. Although the women were eminent, they often displayed humility or struggled with their self-confidence. For instance, when Jodie went up for tenure, she alternated between positive and negative self-talk:

> I remember feeling sure that they would give me tenure, then the next moment thinking there would be no way it would happen. There were so many talented people in the department. I'm not sure I really saw myself as one of them. (Jodie, personal communication, April 3, 2017)
> The women's motivations were intrinsic. Receiving prestigious rewards or other recognition did not bring fulfillment; instead, the women were motivated by passion for their research, a drive to explore and discover, intellectual autonomy, complex problems, and collaborative work. The women's approaches to thinking

> and working showed a preference for complex, difficult problems, an interdisciplinary approach to solving problems, and a creative or innovative thinking style.

The women accommodated, rather than assimilated, many aspects of masculine science ideology that prevails in STEM. Although they positioned themselves as open, communally oriented, innovative and motivated by interdisciplinary solutions, those positions compete with the "hard" masculine STEM discourse—the focus on the distant and abstract, and the dispassionate search for verifiable answers (Schiebinger, 1997). That the women were able to resist assimilation of masculine ways of thinking and working may stem from their openness, exploratory mindset, and nonconformity; the intersection of those qualities with their strong intrinsic motivation for personal fulfillment may be a key factor in the women's ability accommodate masculine aspects of STEM without sacrificing their own feminine ideals and goals.

The women's career trajectories diverged in the beginning and early stages of their academic careers. As children, the women experienced recognition, support, and encouragement from their parents, teachers, or older siblings. Parental support did not depend on the parent's science background. For instance, although Esther's father never graduated from high school, he provided her with encyclopedia, telescopes and chemistry sets (Esther, personal communication, February 9, 2017). As children, the women learned mechanical or technical skills at home that were helpful in their later laboratory work. For example, Esther's father taught her woodworking and car maintenance: "Tools and all that kind of stuff, I was in the shop all the time. That's really important in our lab. It's really important to be able to use tools and to build and take things apart. I just don't think girls get exposed to it" (Esther, personal communication, February 9, 2017). The women's early educational experiences were positive and included home schooling, high school abroad, an all-girls school and a highly funded rural public high school where the majority of faculty held doctorates.

The tempo and pace of the women's paths varied widely, sometimes taking detours, unplanned directions, or leading to specializations relatively late. In some cases, those differences occurred prior to the start of their academic careers. For example, Elizabeth took a gap year to travel after completing her undergraduate degree (Elizabeth, personal communication, March 28, 2017). Jodie found her specialization not by plan, but through a series of decisions motivated solely by her interests and passions (Jodie, personal communication, April 3, 2017), and Leah stumbled on her specialization only after completing her master's degree in another discipline (Leah, personal communication, April 18, 2017). There is a large disparity in the number of years it took to progress from PhD to Full Professor (Table 1), ranging from five-eight years for three of the women and 10-20 years for the others. In the United States, the typical path from PhD to Full Professor includes three years of postdoctoral work, up to seven years to tenure, and five to seven years from tenure to Full Professor. The women who were elevated to full professor in a short span of time had made exceptional contributions relatively early in their careers; all three women began work in graduate school on topics that became major advances in their respective fields.

Early home life and STEM experiences signify an important catalyst of women's later success in STEM. Encouragement and early exposure to science are important for building a strong STEM identity as adult women (Tirri & Koro-Ljungberg, 2002). In childhood, the women experienced nurturing home lives; even the women whose families had relatively lower socioeconomic status still had their physiological and security needs met, and had parents who were attentive, available and consistently supported their STEM interests in concrete ways.

However, the women and their families also held positions as members of the dominant White discourse and may have benefitted from that privileged position.

Social support from mentors and advisors, significant others and support networks contributed to women's persistence through struggles. Social support from male peers is rare for academic STEM women (Charleston et al., 2014). For these women, however, support from male mentors or advisors was available and influenced or even decided the women's choice of career path in STEM. Elizabeth, for example, relied on one particular professor for support and guidance and changed disciplines so that he could advise her doctoral work (Elizabeth, personal communication, March 28, 2017). Jodie, who began college with poor study skills and failing grades was able to reverse course with academic support from a patient, understanding professor who recognized her potential (Jodie, personal communication, April 3, 2017). Women who were in committed personal relationships had partners who were willing to put their own career goals aside to support their partner's advancement; for instance, when Aliza accepted a high-ranking position in another city, her husband put his academic career on hold and took a position outside academia (Aliza, personal communication, February 22, 2017). For Zoe, networking with other people in her discipline had a positive influence on her career path; early in her career, her talks with the "other" woman faculty member in her department offered a source of support when she needed to work through work-related problems (Zoe, personal communication, March 30, 2017).

Environments that offer a communal orientation that emphasizes collaboration and helping are associated with persistence in STEM; however, in STEM settings such an orientation is notably absent (Diekman et al., 2015). To seek support from someone more successful or powerful in the chilly climate of academic STEM unfairly demands an ability to trust and a willingness to yield power. These women's openness, humility, respect for others, strong sense of STEM identity, and willingness to take risks allowed them reach out to others who held higher rank or relatively more power and who were positioned to provide support. Seeking support—a communal goal (Diekman et al., 2015)—competes with the hegemonic discourse of science achievement; asking for support requires that one resist masculine symbols of achievement in science, such as an individualistic orientation toward achievement and competition between individuals for recognition (Talves, 2016). The mentoring experiences of the women in this study may have been positive because the women proactively sought their own mentors; mentees have often found assigned mentors unhelpful (MIT, 2011) or even useless in terms of the professional support they had to offer (Greene et al., 2010). That the women were all White may also have helped them conform to conventional mentoring processes and practices that make up the overarching mentoring narrative; however, women who occupy more than one marginalized position may have different needs that call for differentiated forms of mentoring and career support (Buzzanell et al., 2015).

Delays and detours along these women's career trajectories were largely unrelated to family responsibilities. STEM is a heavily masculinized context, and typical women in STEM encounter a substantially more work-family contention than their male peers (Moors et al., 2014). For these women, the difference may lie in their resistance to STEM-related gender stereotypes and cultural gender norms; The ability to resist STEM-related gender stereotypes depends on recognition of a woman's STEM identity by powerful others (Pololi & Jones, 2010). For women in relationships, partners must be willing to share family responsibilities equitably, and at times be willing to take the more than a fair share in order to support the women's career advancement. Women who lack a strong STEM identity or who have partners who enforce cultural gender norms may feel less confident seeking out support, and therefore less likely to resist cultural gender norms and challenge the masculine work ethic (Moors et al., 2014).

The women strived for an optimal balance between work and life, and actively and consistently engaged in self-care. The women engaged in physical activity as a way to disconnect from their intellectual lives. Most of the women practiced moderately intense outdoor activities such as cycling, hiking, running and swimming. Paid help was the most common strategy women used to balance work and personal life, but that choice depended on the women's financial means. For instance, although Elizabeth relied on a nanny after her child reached school age, she had become a mother during a postdoctoral fellowship and had not been able to afford paid care when she needed it most (Elizabeth, personal communication, March 28, 2017). Self-care also took the form of self-advocacy. Esther worked with a hostile male colleague she described as "a jerk, in general" and used humor to manage her feelings; for example, knowing his aversion to certain foods, she would sit next to him at group meetings and order those foods (Esther, personal communication, February 9, 2017).

Most of the women coped by conforming to ideal worker expectations, for instance by dividing the day into separate blocks of work and personal time. Others adhered to the norm at personal cost; for instance, although family was very important to Esther and she spoke of having a long-term, stable relationship, she had no children of her own. When STEM women are forced to conform to masculine ideals, they unwittingly reproduce gendered schemas about what it means to be a female or male scientist (Hart, 2016). STEM institutions must work to adapt and accommodate women's family responsibilities in order to offer women options other than conforming to an adverse norm. STEM women need space to interweave family responsibilities with their work. For example, a new mother should be encouraged to bring her baby to the office and breastfeed according to the baby's needs, and caregivers of young children should be encouraged to take time to family emergencies without negative consequences. Such accommodations would also improve women's by creating an environment where the women experience less questioning of their dedication and less pressure to conform to prejudicial work norms. Notably, more equitable orientations would also benefit men with family responsibilities, and over time would shift the norm away from the ideal worker and toward a more practical and balanced working style for everyone.

Institutional supports aided women's advancement. Institutional support in the form of resources (funding, reduced teaching loads, lab space, support staff) and collegial climate played an important role in these women's advancement. It is important to note that these resources are relatively rare in academic contexts and are not generally available to most STEM women (Bilimoria, 2008). Research funding gave these women freedom to find new research problems or delve more deeply into problems, work without feeling rushed and travel. Lab space was essential for women's sense of belonging. For Jodie, her lab space represented a place where she was free to engage in exploratory work whenever ideas hit and when lab space was unavailable, she felt sad, disconnected and powerless (Jodie, personal communication, April 3, 2017). The women spoke of department chairs or executive level leaders who stood by them during challenging periods in their careers. During her tenure as department chair, Claire felt empowered by the dean's support when she was faced with a series of uncomfortable personnel decisions; the dean's backing allowed Claire to make decisions she felt were "right" without fear for her career advancement (Claire, personal communication, February 16, 2017).

Feminist Poststructuralist Discourse Analysis (FPDA) Findings

FPDA can help uncover implicit meanings in participants' narratives (Frost & Elichaoff, 2014). In the interest of space, we selected a subset of three participants whose interviews embodied ideas, beliefs, or experiences related to discourses found in the recurring themes. The discourses of focus in the FPDA include the masculinized nature of science, cultural gender norms and negotiation of power within families. The FPDA considered both verbal and nonverbal language. For instance, the participants demonstrated nonverbal communications such as hesitations, feedback (e.g. nodding or leaning forward), facial expressions, physical tension, pitch and volume of the voice, eye contact and rhythm; those nonverbal expressions revealed implicit meanings. Participants' verbal expressions likewise contained meaning within the use of voice (active or passive), tone, word choice, metaphors, repeated and filler words, coherence (the order of statements), intentionality, situationality (contexts in which remarks are important) and other language structures that suggested meanings that expressed ideas other than those intended by words alone.

Shana's Masculine Epistemology

Shana differed from the other women in her positivist philosophical approach to scientific inquiry; she believed that the purpose of science is to move ever closer toward objective "truth." That orientation began in childhood when she recalled feeling uneasy completing assignments that required open-ended, subjective responses (Shana, personal communication, April 14, 2017). Positivism is associated with masculine ideals of empiricism and lack of reflection on social influences on scientific discoveries (Harding, 1986). Shana's positivist orientation was evident in her fixation on truth and dismissal of subjectivity. For example, she repeated several times the notion that "opinion" is unscientific, while on the other hand, the "truth" that emerges from testing is reassuring:

"There's something comforting about testing the solutions and moving from opinion to something we know is true. Once something has been tested, only then I can believe it is truth." (Shana, personal communication, April 14, 2017)

Traditional science stresses objectivity, rational thinking and separation between the scientist and the object of study (Rosser, 2000). Although Shana alluded to compartmentalizing her beliefs from her work, she softened her assertion with qualifiers such as "I can" (but do not have to) and "possible" (but not definite). Those qualifiers suggest an unconscious feminine influence on her work: "I can investigate ideas systematically without necessarily believing in them. It's possible to be skeptical and still do credible work" (Shana, personal communication, April 14, 2017).

Interestingly, Shana's research focuses on transitional phenomena, or phenomena "about which it cannot be determined whether they belong to the observer or the observed" (Keller, 1985, p. 85). Transitional phenomena and empiricist modes of objectivity appear at odds with one another (Keller, 1985). Shana's selection of research topics that border on the transcendental and her unconscious softening of her division between knowing and believing suggest a form of self-silencing that has not yet been described in prior work (e.g. Fritsch, 2015; McKendall, 2000; Pololi & Jones, 2010).

Claire's Path Through Uncertainty and Doubt

A deeper look at Claire's narrative revealed a number of important decisions that were tied to options most people might perceive as the less prestigious option. She thought through those decisions carefully, however, and made the choice that balanced her own aspirations with her husband's needs. For example, Claire chose a smaller, less renowned university for her graduate studies:

> And then after he graduated, then he got a job in the city, and that's when we got married then, at that time. And we got an apartment that was halfway between the two cities because I didn't know which university I would eventually go to. And it turned out that for what I wanted to do, [small university] was actually the better school. Most people just can't imagine that it would have been better than [large research university] but it really was. I went to graduate school there and then we eventually then moved in closer. (Claire, personal communication, February 16, 2017)

When she spoke of how others perceived her choice, Claire's tone was tentative. Her words attempted to persuade the listener that her choice was right; for example, the smaller school "was actually the better school," and "most people can't imagine" that the smaller school was a better suited to her research goals. Her decision to opt out of a large, prestigious research university in favor of a smaller school would have been difficult and included some amount of uncertainty. She makes clear to the listener that any uncertainty was short-lived: she repeats the word "then" several times and places the context "at that time" in the past. Reliving the experience in her interview revived emotions associated with the decision, and those emotions were conveyed in her tone. In fact, at the end of the interview Claire said, "You dredged up things that I had forgotten about a long time" (Claire, personal communication, February 16, 2017). Claire continued her graduate school story:

It was accommodating all of that stuff, but it's how I ended up there. If it had just been me, myself, I'm sure I never would have ended up there. (Claire, personal communication, February 16, 2017)

As her story unfolded, Claire's tone changed from tentative to confident. Earlier in the story she placed her decision in the context of her relationship; for example, "we got married," "we got an apartment." However, when she spoke of her later experiences her tone communicated certainty that she had made the best decision; for instance, "I went to graduate school," "I ended up." Understanding the hidden uncertainty, self-doubts, and eventual triumph found in Claire's story would be empowering for young STEM women going through a similar process.

Esther's Selective Tolerance of Implicit Bias

Of the women in the study, Esther had the strongest sense of identity as a STEM woman. Her early experiences working with her father and his male employees instilled self-confidence, a dual perspective, and social capabilities that carried over to her professional community of male peers:

> I've always enjoyed working with guys, because that's all I've ever worked with. Typically, I've been the only woman in this department, until just recently, for a while. We just got a new one. I've always enjoyed working with guys. I think it's because I had a really good relationship with my dad. (Esther, private communication, February 9, 2017)

Esther's positive feelings about male peers is supported by her repeated statement "I've always enjoyed working with guys." Esther's dual perspective made her somewhat tolerant of bias in the workplace. She attributed male peers' biases to cultural norms rather than to their own conscious choices:

> Sometimes a lot of unintentional, maybe I don't know if you call it sexism, but things that happen. I guess I notice it a little bit more now than I used to, as I get older. Still doesn't bother me, quite as much, I don't know. It seems like I view it more as a cultural problem. (Esther, private communication, February 9, 2017)

Esther was capable of shrugging off gender bias without serious emotional consequence. Her tone, however, was tentative ("maybe," "I don't know," "I guess," and "it seems") and revealed more discomfort with her experiences than her words conveyed. For instance, she shared an example:

> Whenever we're in a group and we're talking, or even if I go to lunch with guys, they'll start talking about their research and will say, "Oh yeah, this is really good." Whenever I start talking about my research, they always change the subject. The only things they ever talk to me about are administrative things. Like, "How many students do we have," it's never my research. They never, ever talk to me about my research. I don't even think it's on purpose, I don't view it as on purpose. I think it's a cultural thing, more than anything. I don't even think they're doing it on purpose. I typically never, ever would confront them because, to me, it's not that big a deal. Except occasionally, I have. When it's been more blatant or where they said something like ... One of the guys came in and said, "Hey, there's a big committee," that they wanted to form to do some stuff. I thought it was an important committee. They said, "Yeah, yeah, we need you on this committee. We need a token woman on the committee." Well, that really pissed me off. Because I'm like, I'm not your token woman (Esther, private communication, February 9, 2017).

Esther's feelings alternated between tolerance and vexation. She repeated her view that male biases were "not on purpose" three times. However, her nonverbal language became more earnest (leaning forward, eye contact) and communicated aggravation (frown, hand gestures) when she spoke of her male peers' unwillingness to discuss her research. Despite her tolerance and attribution of the bias to culture, Esther found those experiences upsetting.

Esther's way of coping with workplace bias—with calm tolerance and selective confrontation of a few serious incidents—helped maintain her professional status and advance her career. Nevertheless, accepting biased behaviors as "cultural" unintentionally reproduces those very norms.

Discussion

The thematic findings brought to light the women's common traits, motivations, and approaches to thinking. The women were motivated intrinsically by their passion for research and saw research as their priority. However, women are assigned an unfair share of time-intensive advising and service duties (Rosser, 2014) and hidden workloads (Hart, 2016) that consume valuable research time. Resources such as research funding and lab space were also crucial to the women's empowerment and advancement. Funding gave the women freedom to travel to conferences or reduce their teaching loads, leaving more time for research. Lab space represented both psychological security and a creative outlet where women could freely explore ideas whenever the ideas hit. Department chairs can help by distributing workloads evenly, recognizing the cost of hidden workloads and ensuring that faculty women are not being exploited (Hart, 2016).

The women developed a range of mechanical and technical skills as children; those skills proved useful in their later lab work. Participants in this study may be exceptional in their early development of those skills because they learned the skills at home rather than in school. Not all girls, however, have opportunities to learn technical and mechanical skills at home. Schools should implement programs or curricula aimed at teaching girls a range of research and technical skills stereotyped as naturally "male." Because mechanical and technical skills are masculinized, girls may be vulnerable to stereotype threat; such stereotypes potentially harm girl's STEM self-efficacy and may discourage their interest in STEM (Smeding, 2012). Acquiring those skills can empower girls with a sense of confidence they might otherwise lack in lab settings.

To maintain balance between work and personal life, the women depended on paid help. For early career women with children who could not afford paid help, the absence of institutional support left them reliant on family or friends to provide childcare. When postdocs and faculty perceive their workplace climate to be amenable to family-work balance, they have more positive outcomes (Moors et al., 2014). Further, institutions should consider the possibility that women's financial status could interfere with their career advancement (Kachchaf et al., 2015). Institutional leaders must identify weaknesses regarding institutional family-friendly policies and implement new policies to maximize work-family balance.

As described in the FPDA findings, Shana's suppressed subjective epistemology may have influenced her work to some extent, at the very least in her passion for ill-defined, complex, transcendental problems. Further research exploring academic women's epistemological and philosophical beliefs around science is warranted. Claire's narrative revealed the doubts and uncertainties women contend with during the process of making important decisions. Future research could explore women's critical career decisions in greater depth; the findings would be empowering for young women facing difficult career decisions and could help mentors better understand and support their mentees. Regardless of the strength of their gender and STEM identities, STEM women's tolerance of biased behaviors can unintentionally reproduce biased norms in STEM. Action research, for example conducted in a support group format, would offer a way of transforming STEM culture while raising awareness in the academic community of how implicit bias survives over time. Action research is empowering for women because it focuses on societal change rather than placing responsibility for change on women's personal agency; the latter approach tends to reinforce the gendered organization rather than transform it (Hart, 2016).

Although the women in the study were primarily White and identify with their sex assigned at birth, the women occupied multiple contextual positions that interacted, varied across contexts, and changed over time. However, research on STEM women tends to view women as a homogeneous group with similar needs and obstacles and treats gender and ethnicities separately, obscuring their complex intersection (Wang & Degol, 2017). For instance, Black women who experience the intersection of sexism and racism may identify as either Black, female, or both depending on the situational context (Charleston et al., 2014). Factors that support diverse women's success in STEM could be better understood by extending the current inquiry to women STEM faculty who are marginalized in more than one way. Specifically, experiences of academic STEM women who identify with a gender different from that assigned at birth appear to be an unexplored matter.

Detailed studies of context within academic STEM may also be useful (Bilimoria et al., 2008). Future research should consider differences in women's experiences across disciplines and institutions. For example, communication styles may vary across disciplines and although talented STEM women are protected to some degree by their high verbal ability, many find the assertive communication style typical of some disciplines uncomfortable (Herzig, 2004). An extension of the current study could focus closely on women's communications within a single discipline, perhaps limiting participants to a small number of cases to allow a deep analysis.

Maternal wall bias is a form of discrimination that occurs when mothers, pregnant women, or primary caregivers are perceived as less competent or committed to their jobs (Luceno, 2006). Parenthood and motherhood are key factors in the discrimination experienced by women in STEM, and maternal wall bias increases with number of children (Williams & Norton, 2008). Although some women in this study offered their parental status, maternal wall bias was not addressed as a factor in this study. The authors recommend expanding the current study to explore the experiences of women STEM faculty with maternal wall bias, and its effects on their careers.

Finally, there is need to further examination of women's success from qualitative, feminist perspectives (Mullet et al., 2017). Traditional research assumes an objective, value-free perspective that tends to elevate the researcher's position while subjugating the perspectives of the "researched;" feminist methodologies challenges those premises by elevating women's experiences and perspectives (Hesse-Biber, 2014). One extension of the current study surrounds the relationship between women's representation in a discipline and the discipline's opportunities for empathetic reasoning. For instance, STEM careers are conceived as less likely than other disciplines to afford opportunities to help others (Diekman et al., 2015). Future inquiries could give attention to women's communal goals and experiences in their disciplines.

Limitations

Trustworthiness has been demonstrated on several dimensions including (a) triangulation of analytical methods, (b) thick description of findings, and (c) reflexivity, or the investigator's ongoing process of reflection on theoretical bases that inform the study. The well-being of participants was protected by following guidelines for ethical research with human subjects; in particular, participants' anonymity has been strictly protected. Although the findings can be transferred to similar contexts and participants (e.g. senior faculty at other institutions), the findings are specific to the study's participants and context and cannot be generalized in a broad sense. The interviews were limited to 90 minutes in length to respect participants' time constraints; this population of elite women was difficult to access due to multiple demands on their time. Finally, the sample included only White women and does not represent the experiences or perspectives of women of color.

Conclusion

The study explored the academic and career experiences of high-ranking women STEM faculty for factors that activated their success. The participants shared many traits, motivations and coping strategies, and those personal-level strategies are important contributors to women's satisfaction and advancement. However, the burden of agency should not be placed solely on the women, but instead should be shared by the institution.

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Table 1

Participants

Pseudonym	Age	Years from PhD to Full Professor	Ethnicity	Relationship	Children
Aliza	40-49	5	Caucasian	Married	Yes
Claire	60-69	20	Caucasian	Married	Yes
Elizabeth	60-69	15	Caucasian	Divorced	Yes
Esther	50-59	20	Mixed	Committed relationship	No
Jodie	60-69	10	Caucasian	Single	No
Leah	50-59	8	Caucasian	Married	Yes
Shana	50-59	15	Caucasian	Single	No
Zoe	30-39	8	Caucasian	Married	Yes

Table 2

Thematic Findings

Themes	Subthemes
The women shared many traits, motivations and approaches to thinking and working.	Personal traits: openness, agreeableness, persistence, and high self-confidence. Motivations: intrinsic goals, collaboration, and altruism. Approaches to thinking and working: a creative or innovative thinking style, interdisciplinary perspective on problem solving.
The women's early STEM experiences were similar, but their paths diverged through the beginning and early stages of their academic careers.	Early support and encouragement from adults or older children. Access to high quality or alternative education. Critical decisions were driven by either their women's interests or family concerns.
The women recognized the need to balance the work and life, and actively and consistently engaged in self-care.	Physical activity and exercise. Time-saving strategies. Self-advocacy.
The tempo and pace of women's paths varied widely and included detours, unplanned directions, and late development of specialization.	None
Social support from mentors and advisors, significant others, and support networks were important contributors to women's persistence through struggles.	None
Institutional supports aided women's advancement in the form of research funding and resources (e.g. lab space), organized support groups, and supportive department chairs.	None

Appendix A

Demographic Survey

Name:	
E-mail:	
Year of birth:	
Gender assigned at birth:	Male / Female / Other / Decline to answer
Gender:	Masculine / Feminine / Androgynous / Transgender / Fluid / Other / Decline to answer
Race/ethnicity:	White / Black / Chicana or Latina / Native American / Asian or Pacific Islander / More than one ethnicity (please describe) / Decline to answer
Discipline:	Physics / Chemistry / Technology / Computing / Engineering / Mathematics / Other
If other, specify:	
Relationship status:	Married / Committed partner / Single / Other / Decline to answer

Approximately how many times have you been published in scholarly, peer-reviewed journals?

How many times have you been principal investigator (first author) on published research?

How many times have you presented research findings at national conferences or meetings?

Have you ever received an award for original scientific research?

How much have you received in internal or external funding for your research?

Prior to college, did you ever participate in a STEM enrichment program such as a science or math summer camp? Yes / No

Appendix B

Semi-structured Interview Guide

1. Tell me about how you made your career choice. What led to your choice? When did you first know? How did people around you respond to your choice?
2. Describe a specific event in your education or career that you found supportive or positive. Describe your memory: setting, people, impressions, and feelings.
3. Think of someone who influenced your success. Describe the person, the circumstances of your relationship, the person's impact on your career, and your feelings about the person.
4. Think of a specific place (e.g. a department or school)--part of your work life—that you remember as a positive or supportive place. Describe the place.
5. Think back to an important transition in your career that marked advancement or recognition. Describe the transition: events leading up to it, people involved, and your thoughts and feelings during the transition.
6. Do you have a childhood memory of a person, place, or event associated with STEM? Describe the memory in as much detail as you can.
7. Tell me about your personal qualities or characteristics that you have found helpful throughout academic life.
8. Tell me about a difficult decision you had to make at some point along your career path. Discuss the decision, the options you faced, and your thoughts and feelings throughout the process.
9. If you're comfortable doing so, tell me about your fundamental beliefs or values. What role do they play in your academic life?
10. Is there anything else you would like to share?