

CATALYSTS OF WOMEN'S SUCCESS IN ACADEMIC STEM:

A FEMINIST POSTSTRUCTURAL ANALYSIS

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This study analyzes senior women faculty's discourses about personal and professional experiences they believe contributed to their advancement in academic careers in science, technology, engineering, and mathematics (STEM). The purpose of the study is to understand factors 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 women navigate social inequalities, hierarchies of power, and non-democratic practices. Feminist poststructural discourse analysis (FPDA) methods allow analysis of women's talk about their experiences in order to understand the women's 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.

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## CATALYSTS OF WOMEN'S SUCCESS IN ACADEMIC STEM:

### A FEMINIST POSTSTRUCTURAL ANALYSIS

As researchers, women faculty members are valuable contributors to the diversity and creativity of the scientific community, 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 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—women 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 the Abel Prize has been awarded only to men in the 14 years since it was established ("The Abel Prize," 2017).

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 (Nelson, Brammer, & Rhoads, 2010) paint a bleak picture: 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).

## Reasons for Underrepresentation among Senior Faculty

Research conducted over the past decade on women's status in science and engineering highlights a number of obstacles and challenges that limit women's representation at the upper levels of academic careers in STEM. Recurring themes include women's feelings of isolation, unfavorable institutional climates, uneven work assignments, lack of mentoring and social support, implicit gender bias, and lack of alignment between women's core values and the foundational values of western science.

### The Double Bind

The term "double bind" (p. 1) signifies the intersection of race and gender marginalization experienced by women of color in STEM; their multiple oppressions place women of color among the least valued and most marginalized underrepresented groups in STEM (Malcolm, Hall, & Brown, 1976). Although women of color face the same gender-associated obstacles and barriers that all STEM women face, their racial status creates additional challenges that demand valuable time spent navigating racial barriers—time that would otherwise be spent on career advancement (Hodari et al., 2016). Types of obstacles faced by women of color in STEM are related to environments where the women feel isolated and unwelcome (Hodari et al., 2016; Johnson et al., 2011). These women contend with subtle racist and sexist microaggressions, intractable interpersonal relationships with administrators or peers (Hodari et al., 2016), others' low expectations (Hodari et al., 2016; Kachchaf et al., 2015), and inadequate mentoring (Buzzanell et al., 2015; Hodari et al., 2016; Johnson et al., 2011).

Additionally, women of color experience different challenges around work-life balance from their peers who more closely embody the norm (Kachchaf et al., 2015).

#### Sense of Isolation or Outsider Status

Isolation is a serious issue because it can be a major source of job dissatisfaction among female STEM faculty and can provoke their decision to leave academia (Hill, Corbett, & St. Rose, 2010). Studies suggest that for its members to move from being isolated and at-risk to becoming integrated, a minority group must reach a critical mass of 15-20% (Etzkowitz et al., 2000). STEM women who lack identity-group peers struggle to understand and validate workplace experiences (Pololi & Jones, 2010). When a discipline is dominated by men and founded on male protocols, a man and woman entering the discipline for the first time may experience it differently. The man's masculine gender and prior experiences locate him in a socially familiar setting that enables his work to proceed immediately. The woman, on the other hand, becomes aware of being an outsider in a social situation that contradicts gender norms; her sense of otherness means that she must spend valuable time and energy working through decisions about her identity and appropriate behaviors (Nye, 1997).

#### Social Exclusion from Informal Networks

As a numerical minority, women faculty in STEM are often excluded from informal work-related networks and isolated from male colleagues (Cain & Leahey, 2014). DeWelde and Laursen (2011) found that especially in the math-intensive science disciplines, women are excluded from "old boys' clubs" that control access to knowledge, mentoring, and

opportunities. In another study, STEM women reported having few or no networks within their institution, felt that mentoring and collegiality were absent, and reported feeling isolated and unrecognized by colleagues for their work (Hart, 2016). Some consequences of social disconnection from informal networks include decreased access to social support and camaraderie, mentoring, opportunities for advancement and funding, and extended networks (Xu & Martin, 2011). One group of female academics indicated informal communication as a career obstacle, citing informal encounters and off-the record remarks as decisive factors in social exclusion (Fritsch, 2015). Research into the experiences of women of color in STEM identifies environments in which the women felt their persistence and advancement threatened by factors such as challenging interpersonal relationships with colleagues, colleagues' low expectations, and lack of mentoring and social support (Hodari, Ong, Ko, & Smith, 2016). One postdoctoral woman of color described being excluded from social outings with her advisor and her male colleagues, for example to go sailing or meet for drinks; instead, her invitations were limited to family events, such as her advisor's children's birthday parties (Kachchaf, Hodari, & Ong, 2015).

### Chilly Institutional Climate

In recent years, a number of universities have conducted climate surveys, discovering in some cases that a chilly institutional climate (Sandler & Hall, 1986), defined as behaviors that devalue, exclude, or marginalize women (Maranto & Griffin, 2010; National Academy of Sciences, 2006), hurts the advancement of STEM women (National Research Council, 2010). Climate becomes more chilly as women progress through their careers, making their jobs

increasingly difficult and less satisfying (Hopkins, 2002), and STEM women full professors report a chillier climate than their less senior counterparts (Borland & Bates, 2014). One group of researchers visited several chemistry departments where female faculty members described their contributions as undervalued and the climate for women hostile and unsupportive, yet male faculty members in the same departments were generally unaware of the chilly climate (Chapman et al., 2011). STEM women are also less likely than men to characterize their departments as exciting, helpful, creative, and inclusive, and are more likely to characterize their work setting as stressful (Fox, 2010).

#### Uneven Resource Allocations, Work Assignments, and Evaluations

Inequitable distributions have been found in terms of space, salary paid from individual research grants and by institutions, teaching assignments, awards and distinctions, inclusion on important committees, and assignments within the department (Hopkins, 2002). Differences in the resources and privileges awarded to men and women faculty can be substantial, especially in areas that are most likely to be related to career advancement such as salaries, workload, space, and recognition for research (Stockard, 2013). STEM women are disproportionately targeted to perform advising, mentoring, service, and administrative duties because they are rare in their departments (Rosser, 2014). Mid-career women described inequitable or “hidden” workloads, usually assigned by male department chairs, such as new course assignments or time-intensive service obligations—none of which advanced them toward promotion (Hart, 2016).

## Ineffective Mentoring

Women perform a disparate share of caregiving functions, such as teaching and mentoring, in the academy despite their preference to engage in research activity (Hart, 2016; MIT, 2011). Women in turn receive inadequate or even useless professional support through mentoring (Greene, Lewis, Richmond, & Stockard, 2010). Women who did receive mentoring often described the experience as positive (Hart, 2016; MIT, 2011), but assigned mentors were not always helpful, and in many cases women felt the need to be proactive in finding their own mentors (MIT, 2011). The mission and aims of formal mentoring programs tend to be general in nature and do not always align with women's specific needs (Buzzanell, Long, Anderson, Kokini, & Batra, 2015; MIT, 2011). For instance, women in engineering participating in formal mentoring felt vulnerable during the process, and ended the process feeling disenchanting and less confident (Buzzanell et al., 2015).

## Implicit Bias and Stereotype Threat

Implicit gender bias still pervades STEM. Implicit bias appears in reactions to the awards and achievements of faculty women; for instance, women faculty noted that when they won an award or were formally recognized, colleagues often responded by commenting that the award "was long overdue to be given to a woman" (MIT, 2011, p. 13). Implicit bias also affects personnel decisions in academic STEM (Berheide, 2016; MIT, 2011). For instance, both male and female search committee members are likely to exhibit implicit gender bias toward candidates in the academic job application process (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012). Implicit bias also appears in the wording of job advertisements in male-



dominated fields (Gaucher, Friesen, & Kay, 2011). The likelihood of women being promoted to full professor may result from the ambiguous and uneven application of promotion standards to men and women (Fox & Collatrella, 2006).

Because women in STEM disciplines are judged against masculine stereotypes, they may appear less competent in spite of having capabilities and experience equal to or better than that of their male colleagues (Corbett & Hill, 2015). Women are stereotyped as lacking innate talent in the hard sciences, and for that reason are more likely to be underrepresented in fields such as science and mathematics, where practitioners believe innate intellectual brilliance is the main requirement for success (Leslie, Cimpian, Meyer, & Freeland, 2015). A pattern known as "the tightrope" leaves STEM women negotiating a narrow space between being envisioned as too feminine to be competent or too masculine to be likable (Williams & Smith, 2015). Feminine appearance may wrongly signal that they are incompetent (Borland & Bates, 2014) or not well suited for scientific pursuits (Banchefsky, Westfall, Park, & Judd, 2016).

Stereotype threat signifies the potential for an individual to display decreased performance in contexts in which he or she is at risk of conforming to a negative self-relevant stereotype (Schmader, Johns, & Forbes, 2008). Stereotype threat impedes interest and motivation in the stereotyped domain (Diekman, Weisgram, & Belanger, 2015), and undermines women's confidence, for instance by leading women to question whether they were hired for their talent or simply to increase female representation (MIT, 2011). The stereotype that marks women as less competent in STEM than men can inhibit women's communication with male colleagues in the STEM workplace. In one study, for instance, women's level of engagement in research-related discussions with male colleagues was

inhibited by the threat of “talking shop” with potentially sexist men (Holleran, Whitehead, Schmader, & Mehl, 2011). Stereotypes that portray women as weak or needy were found to hold women back from taking advantage of family-friendly policies (for example, part-time tenure track appointments or stopping the tenure clock for a major life event; Thomas, Bystydzienski, & Desai, 2015). Women faculty may be reluctant to take advantage of such policies because they fear being perceived as less committed or professional than their peers (Moors, Malley, & Stewart, 2014).

### Masculinized Nature of STEM

Feminist philosophers of science suggest that the traditional physical sciences are epistemologically, ontologically, and emotionally “hard” in that they emphasize objective, verifiable answers, focus on inanimate matter, and are thought to be distant, abstract, and dispassionate (Schiebinger, 1997). Gilligan (1983) associated the “hard” qualities with the masculine gender, while on the other hand, characterized the feminine gender as communal, caring, and emotional, and suggested that women draw meaning and fulfillment from engagement in communal work. Characterized primarily by the motivation to serve others, the goal congruity perspective suggests that STEM fields deflect communally-oriented individuals because those fields are *perceived* as unlikely contexts for actualizing communal goals (Diekman et al., 2015). Some women tend to select out of STEM careers because women especially endorse communal goals: Diekman et al. (2015) found that communal goal orientation negatively predicts interest in STEM, even when controlling for aptitude and self-efficacy in math and science (Diekman et al., 2010). Although the natural and social sciences

have a clear social purpose, the physical sciences offer fewer socially relevant opportunities (Corbett & Hill, 2015). Incongruities between masculine and feminine value systems and ways of thinking in STEM may lead to women's feelings of isolation and disengagement from their STEM careers, and women who are unable to reconcile differences between their ideals and available communal opportunities may leave STEM in search of fulfillment elsewhere.

### Ideal Worker Norm

The "ideal worker" signifies how norms at work are constructed through beliefs of what it means to be a good worker. In academic settings, the ideal worker presupposes a style of working that follows men's life patterns, for example a family model in which mothers stay home and care for children while fathers work outside the home and provide economic support (Hart, 2016). The ideal worker norm interferes with women's success in academic contexts, where women are subject to different role expectations and encounter more work-family contention than their male peers (Moors et al., 2014). STEM women note that childcare issues tend to be perceived as woman's issues rather than gender-neutral family issues (MIT, 2011), and recognize conflict between having a family and a career in STEM (Moors et al., 2014).

Raising children may have special consequences for STEM faculty because timing parenthood simultaneously with a research career may conflict more than in other career paths (Diekman et al., 2015). For instance, the requirement for geographic mobility may be difficult to fulfill while starting a family (Fritsch, 2015). Being part of a dual-career couple also has particular implications for STEM women because female scientists are more likely to have life partners who are also scientists (Diekman et al., 2015). Some couples manage the issue by

spending extended periods of time working in different cities, or by one partner taking a less desirable position while both work in the same city; both solutions put intense strain on a committed relationship (MIT, 2011).

### Factors that Support Women's Success

While numerous factors impede women's ability to be successful in STEM, the literature on academic STEM women revealed a number of individual factors that cultivate their success.

#### Persistence

The ability to persist through layers of challenges plays an important role in the professional success of STEM women faculty. Successful women 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. Persistence can also bring rewards that transcend career advancement; for example, one woman engineering professor felt a sense of pride when others recognized the profundity of her accomplishments as a single Black mother in a demanding and hostile male-dominated field (Kachchaf et al., 2015).

#### STEM Identity

Talented female scientists build the foundations of their STEM identities in childhood,

and merge their notion of feminine identity with scientist identity early in life (Tirri & Koro-Ljungberg, 2002). Women who establish successful academic careers in STEM circumvent the social identity threats that prevent other women from feeling included in STEM fields (Richman, Vandellen, & Wood, 2011). One advantage of a well-developed identity as a woman scientist is the capacity to reinvent the notion of “scientist” in ways that resist the masculine gender norms that pervade STEM. For instance, when confronted with barriers in their STEM work, some women of color responded by expanding their STEM identities to include their altruistic values (Hodari et al., 2016). A second advantage is self-awareness and acceptance of their positions as outsiders. Women who accommodated their outsider positionality were able to use their dual perspectives to conceive of possibilities that transcended mainstream thought (Pololi & Jones, 2010). However, the success of composing a STEM identity as a strategy for persisting in STEM depends on recognition of that identity by people in power (Johnson, Brown, Carlone, & Cuevas, 2011). Ideally, recognition of a woman’s STEM identity by powerful others serves as an avenue for reconstructing gender norms and feminizing science. For example, women who forged feminine STEM identities often used their power and self-confidence to help other STEM women overcome obstacles (Pololi & Jones, 2010).

### Effective Coping

Coping strategies are “consciously chosen, intentional behaviors and cognitions that can flexibly respond to environmental demands” (Aldwin & Yancura, 2004, p. 1). STEM women employ a variety of strategies to confront challenges and obstacles (for example, challenges to achievements, advancement, and comfort) associated with being a woman in a math-intensive,

male-dominated discipline. Specifically, STEM women rely on strategies focused on organization and time management, social support, communication and soft skills, personal meaning, and self-silencing.

### *Organization and Time Management Strategies*

Career advancement in academia depends on effectively dividing time and labor between research, teaching, and service. The three divisions carry different weights in the tenure and promotion process; in STEM, research is the most highly valued. As a result, women who attain senior faculty positions see research as their priority and actively engage in research and grant writing (Hart, 2016). To balance the demands of work and family, some women compartmentalize their lives into two completely separate realms, one confined to professional obligations and the other to private life (Fritsch, 2015). To prevent work from becoming the center of their existence, some STEM women limit their time spent working to a fixed number of hours (no more than 50-60 hours per week, for example), and spending free time engaging in activities that get the mind “out of the intellectual realm” (Pololi & Jones, 2010, p. 446). Some women also choose not to divide their roles; instead, they subordinate family needs to their work life. For instance, if a woman’s career requires a geographic move, her partner follows her (Fritsch, 2015). Some women coped with competing demands by creating unique microenvironments within their discipline (Fritsch, 2015; Pololi & Jones, 2010). For instance, by creating a niche within her field, one woman faculty member was able to secure a grant and increase her work flexibility, which in turn increased her happiness and improved the quality of her life (Pololi & Jones, 2010).

### *Social Support Strategies*

STEM women often cope by seeking social support or assistance; for instance, social support provided by others can serve as a protective factor and strengthen women's self-confidence under conditions of social identity threat (Richman et al., 2011). The networking system is another coping strategy employed by many STEM women. Networks provide opportunities for women to interact with other women who share their interests and problems. Although networks serve a social function, they also signify a strategy for building relationships and connections with others (Gilligan, 1982); through networking, women listen to one another, offer much-needed advice, and build trust (McKendall, 2006). When networks are unavailable in their institution or department, some women cope by drawing on outside networks such as graduate school faculty or cohorts, former mentors or advisors, or peers at other institutions (Hart, 2016). Women who have the financial means cope with demands on their time by hiring paid help such as full-time housekeepers or nannies. Relying on paid help reduces stress for mothers of young children especially, in the sense that it eases worries about getting children to school on time and caring for them during the workday if they fall ill (Pololi & Jones, 2010).

### *Communication and Soft Skills*

STEM women use diplomacy and open communication as coping strategies. For instance, one woman coped with malevolent talk in the workplace by responding immediately (Fritsch, 2015). STEM women of color employ specific strategies for coping with the challenges of the double bind, or the intersection of racism and sexism (Malcolm et al., 1976) in their work

lives. Some women of color develop or rely on soft skills (e.g. interpersonal or communication skills) to deal with obstacles, advocate for themselves, and support their own advancement (Hodari, 2016). For instance, one Black woman developed a rapport with her White male manager that allowed her to speak with him frankly on issues related to diversity and inclusion in their work setting (Hodari, 2016). Other women of color take a more direct approach; when one woman recognized that African American stereotypes were influencing her department chair's opinion of her work, she confronted him directly and specifically addressed the racial component of her treatment (Kachchaf et al., 2015). Clarifying that her treatment was based on her cultural identity and not her STEM identity helped to protect her professional self-efficacy (Kachchaf et al., 2015).

### *Meaning-Making*

Women sometimes relied on their personal backgrounds and life experiences to find problems that were personally meaningful and socially relevant (Hodari et al., 2016). For instance, one Black engineering scholar's childhood experiences sparked her interest in energy consumption in low-income communities; another Black scholar in computing applied her work in ways that would help raise self-esteem for girls of color (Hodari et al., 2016).

### *Self-Silencing*

For some women, choosing silence is a way to cope with feelings of vulnerability while protecting career advancement and gaining influence (Pololi & Jones, 2010). Silence is also a means of preserving time and energy. For instance, some women faculty avoided informal



contact and ignored insinuations in order to devote less time and energy defending themselves; instead, the women maintained a professional distance and spent their time on professional tasks and responsibilities (Fritsch, 2015). Women sometimes suppressed their feminist ideals when interacting with male colleagues in order to avoid being labeled as a militant female, explaining their choice as a political tactic intended to avoid conflict and focus others' attention on their professional contributions (McKendall, 2006). Others hid their roles and responsibilities as mothers to position themselves to be perceived as "ideal workers" (Hart, 2016). Self-silencing was also a means by which women could secure a position of power from which to make women-friendly institutional changes; for these women, self-silencing also took the form of extra work hours or attendance at unnecessary meetings (Pololi & Jones, 2010).

### Critical Decisions

For many STEM women, parents' involvement and support played a significant role in their choice to pursue STEM; in many cases one or both parents were scientists or engineers (McKendall, 2006). Family considerations influenced women's decisions to pursue academic careers in STEM. Women with children anticipated more flexibility in work arrangements in academia than would be found in industry; for instance, the timing of holidays in academic settings coincides with children's school holidays (McKendall, 2006). STEM women's passion for research drives the decision to dismiss leadership opportunities; women faculty believed taking a leadership position would permanently sever their connection to their research life (Hart, 2016). However, women recognized the advantages of international research experiences and

collaborations, and took advantage of such opportunities when they believed it would advance their academic careers (Fritsch, 2015; Tirri & Koro-Ljungberg, 2002).

### Supportive Institutional Factors

Features of institutional environments matter; for instance, resources such as funding, reduced teaching loads, lab space, and support staff help both men and women advance in their academic careers (National Research Council, 2010). Institutional supports that contribute specifically to women's advancement in STEM include positive climate, mentoring, and peer support networks.

#### *Positive Climate*

A fundamental determinant of women's persistence in STEM careers is the workplace climate (Hodari et al., 2016). Collegial, positive departmental climates are especially important for women and minority faculty members (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). When STEM workplace environments accept and value women's professional contributions, women are more likely to feel a sense of belonging in the field despite the presence of gender bias; for instance, women engineers who were treated fairly and whose exposure to discrimination was negligible were less vulnerable to social identity threat (Richman et al., 2011). Supportive department chairs (McKendall, 2006) and perceived institutional support for family responsibilities (Moors et al., 2014) are additional components of positive climate that heighten women's sense of belonging and job satisfaction.

### *Mentoring*

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). Actively seeking a mentor contributes to some women's success. For instance, during the negotiation process for her faculty position, one woman asked the department chair to assign a formal mentor; she was assigned two mentors and worked with both to accomplish different career needs (Stenken & Zajicek, 2010). Departments with larger numbers of female faculty members understand the challenges faced by STEM women and provide more effective mentoring to young women faculty members (Buzzanell et al., 2015).

### *Peer Support Networks*

Peer support groups represent a means of providing meaningful, long-term support to women who are marginalized in their disciplines (Greene, Stockard, Lewis, & Richmond, 2010; Stockard & Lewis, 2013). STEM women benefit from participation in peer support groups by sharing tangible problems with similarly positioned women (Thomas et al., 2015). 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). Peer support groups also act as catalysts by positioning women to promote change in academia (Stockard & Lewis, 2013); for instance, participants in

one group collectively developed and proposed a set of policies focused on advancing the interests of female faculty (Thomas et al., 2015).

### Purpose and Research Question

Using women's perspectives, the study examines how women describe lived experiences that contributed to their career success. The purpose of the study is to identify factors that activate women's success in STEM disciplines where women's representation has not yet attained critical mass. An additional aim of the study is that of raising awareness of the warrant 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?

### Theoretical Framework

Poststructural feminism challenges the essentialist notion that women constitute a single, static category of identity instead, poststructural feminism 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 the same professional context, STEM women are varied in many ways including educational background, race, nationality, gender identity, relationship status, and the intersections of any or all 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 & Elichaooff, 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). Poststructural feminism creates a space for exploring complex intersections of identities including but not limited to gender, race or ethnicity, and social or professional status, opening up the possibility of differences that have not yet been imagined (Butler, 1992).

### Significance

Regrettably, a dearth of empirical research exists to explain how or why those exceptional women persist where so many other capable women fail to reach their potential (Mullet, Rinn, & Kettler, 2016). The intention of the current study is to bring new perspectives to this understudied topic and support social transformations 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 from STEM. Instead, the current study instead takes a positive perspective and expands the literature by exploring women's strengths, actions, external supports, and other factors that foster their success in STEM. Second, few prior studies on this topic have employed feminist research methods (Mullet et al.); more specifically, feminist post-structuralism has yet to be used widely in feminist educational research (Baxter, 2002). The qualitative, feminist 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 help fill that gap in the literature.

## Method

### Participants and Data

Participants in the study (Table 1) were purposively selected based on the research question: we sought a sample of elite female STEM faculty members, specifically those holding full professorships in physics, chemistry, engineering, and mathematics from diverse demographic backgrounds. Because the logic of qualitative research is concerned with in-depth understanding, samples are often small (Hesse-Biber, 2014). To allow time for an in-depth analysis, we initially limited our sample to 10 participants. 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.) at the time of sampling (early 2017). Each institution with a publically available online faculty directory was searched for female, tenured full professors in physics, chemistry, computer science and engineering, or mathematics. The principal investigator selected 40 potential participants and emailed invitations to participate in the study. Initially, 23 women responded and were asked to complete an online demographic survey (Appendix A) and provide a current curriculum vitae. Eleven women completed demographic surveys and were contacted to schedule an interview.

Eight women responded and were included in the study. The women are referred to by pseudonym in the study to ensure their anonymity.

Data items included in-depth interviews, demographic survey responses, and participants' curricula vitae; the curricula vitae were used to compare the pace and timing of events along women's career paths, for example the time from Ph.D. to attaining full professor rank (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. When necessary, the investigator followed up with participants for clarification or elaboration.

At the conclusion of data collection, transcript data files were imported into NVivo, and a case record defined for each participant. NVivo was selected for its ease of use and flexibility. The software allows direct import of a variety of document formats such as word processor and PDF files, and coding can be done easily on screen. Although NVivo is based on grounded theory approaches, it can also be used with other approaches (Leech & Onwuegbuzie, 2011). For example, although the grounded theory coding paradigm is a mixture of inductive and deductive approaches, NVivo supported the inductive coding procedure used in this study.

## Data Analysis

The analysis was framed as a multiple case study. The 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 particularly appropriate for investigating and writing about 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. Further, thematic analysis helped identify discourses that warranted deeper examination in the second stage of analysis. The second stage, feminist poststructural discourse analysis, examined discourse found in the first stage in more depth to reveal the complexity of the women's multiple, competing positions within their male-dominated, masculinized academic contexts.

### *Thematic Analysis*

Themes recurring across the collection of interview transcripts were identified using thematic analysis, a qualitative data reduction method for identifying patterns or themes within data (Braun & Clarke, 2006). Thematic analysis proceeds through six steps. The first step involves immersion in the data; in this study, immersion was accomplished through multiple close readings of the transcripts. Coding takes place in the second and third steps; here, data were coded using an inductive coding procedure; the procedure creates a set of summary categories that capture important meanings represented in the raw data (Thomas, 2006). NVivo was used to facilitate management and visualization of the data by storing and tracking cases and data sources, by acting as a platform for coding and categorizing data, and for visualizing the progress and results of the analysis through the use of tools such as text queries, hierarchy charts, and explore diagrams. To generate codes, the investigator used an NVivo coding procedure similar to that outlined by Leech and Onwuegbuzie (2011). As each data item was



read line-by-line in NVivo, text segments (usually a sentence in length) relevant to the research question were selected, then each segment was assigned to a node. If the text segment did not fit the meaning of an existing node, a new node was created for that segment. Each node in NVivo contained one or more text segments and was automatically cross-referenced by a unique node identifier and case, and each text segment was referenced by its case and location within its source. At the conclusion of the initial coding step, there were 852 text segments grouped into the 83 preliminary nodes shown in Appendix C.

In Step 4, the nodes 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 that were poorly represented in the data (nodes that appeared in fewer than two cases or covered fewer than two segments) reduced the number of nodes to 15, comprising six major themes and nine subthemes (Table 2). The themes represented factors that catalyzed women’s success in their STEM careers. The fifth and sixth steps in thematic analysis assign each theme a meaningful summary description and produce a thick description of the themes. Thick description provides a rich account of both the participants’ experiences and the contexts in which their experiences took place (Geertz, 1973).

#### *Feminist Poststructuralist Discourse Analysis (FPDA)*

Baxter (2003) defined FPDA as a feminist approach to analysing the ways in which speakers negotiate their identities, relationships, and positions in their worlds. FPDA views identities as constructed according to the intersection of multiple categories including gender,

sexuality, age, race or ethnicity, nationality, social status, and others (Baxter, 2002). The poststructural dimension of FPDA is rooted in Foucault's view of discourse as systematic practices that form the objects of speech (Foucault, 1972). FPDA draws on poststructural principles of complexity, ambiguity, recognition, connection, diversity, and transformation, and regards gender difference as a pervasive discourse that crosses cultures in terms of its power to discriminate people according to gender, sexuality, and their intersection with other culturally salient categories (Baxter, 2008). 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 involved a denotative microanalysis of the interview data. Denotative microanalysis makes a close, detailed, but non-evaluative description of speakers' verbal and nonverbal language; denotative analysis is a form of interpretation that depends on the analyst's selection of focus within the data. Connotative analysis was conducted in the second stage. Connotative analysis aims to interpret the selected data in terms of participants' shifting positions of power amid competing discourses.

## Results

### Thematic Findings

The research question sought to identify factors to which high-ranking women in

academic STEM attributed their career success. To answer the question, we performed an inductive thematic analysis of the interview transcripts. The analysis produced five major recurring themes across the sample of participants; those themes signify the broad factors that catalyzed the women's success. The themes are described below and summarized in Table 2.

### *The Women Shared Many Traits, Motivations, and Approaches to Thinking and Working*

The women possessed traits that indicated a high level of openness, including a willingness to take risks, nonconformity to dominant norms, multiple interests and abilities, and receptivity to diversity. The women were oriented toward communal goals and demonstrated care and respect for others, and 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 certain one moment that they would give me tenure, then the next moment thinking there would be no way it would happen. There were so many truly brilliant in the department, and I'm not sure I really saw myself as one of them.

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. For example, early in her career, Shana felt motivated by "the idea of solving a problem that hadn't been solved before." 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 examples that define this theme suggest that 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.

*Although the Women’s Early STEM Experiences Were Similar, Their Career Trajectories Diverged in the Beginning and Early Stages of Their Academic Careers*

The analysis brought to light themes that described influences on women’s career trajectories, beginning as early as childhood. 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 an encyclopedia set, telescopes, and chemistry sets. Many of the women learned mechanical or technical skills at home as children 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.” The women’s early educational

experiences were positive, and sometimes unique; the women's educational experiences 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. Elizabeth, however, attended a high school that did not offer courses in her favorite STEM subject--she gained her first academic exposure to the subject in a summer program for gifted students. The tempo and pace of the women's paths varied widely, sometimes taking detours, unplanned directions, or leading to specializations relatively late; however, 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. Jodie found her specialization not by plan, but through a series of decisions motivated solely by her interests and passions, and Leah stumbled on her specialization only after completing her master's degree in another discipline.

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), and these women drew that support early in life from their families. In childhood, the women all 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. Women who are racial or ethnic minorities, who grow up in poverty, or whose families are psychologically unsupportive require additional guidance and support to develop a strong STEM identity (Buzzanell et al., 2015). Such additional support

could include STEM work that incorporates social justice or altruistic goals (Hodari et al., 2016), developing self awareness and employing their outsider perspective to transcend mainstream ways of thinking (Pololi & Jones, 2010), or through recognition of their potential and achievements by institutions and powerful others (Johnson et al., 2011).

*Social Support from Mentors and Advisors, Significant Others, and Support Networks Were Important Contributors to Women's Persistence through Struggles*

Support from mentors or advisors often 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. 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 high potential. 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 accepted a position outside academia. 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 issues or problems.

To seek support from someone more successful or powerful in academic STEM requires 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 enabled 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 discourse of science achievement; asking for support requires that one resist gendered 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 the women’s career trajectory were largely unrelated to family responsibilities, primarily because the women resisted gender stereotypes and cultural gender norms; this contrasts findings in the literature that suggest women in STEM encounter more work-family contention than their male peers (Moors et al., 2014). For example, although at one point Jodie matched a stereotype that casts women as less capable in STEM (Corbett & Hill, 2015), she did not experience stereotype threat; instead, she sought academic support from a professor who recognized her potential. The ability to resist STEM-related gender stereotypes depends on recognition of a woman’s STEM identity by powerful others (Pololi & Jones, 2010). Successfully balancing family and work responsibilities also depends on women’s resistance to cultural gender norms, especially the norm that positions women as primary caregivers (Hart, 2016). For women in relationships, partners must also resist cultural gender

norms, 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, who defer to cultural gender norms, 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 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 often 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, but a few of the women preferred more demanding activities such as rock climbing or skiing. 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 at the time she needed it most. Although the women described it as challenging, another strategy involved dividing each day into separate parts, for example one block of time for work and another dedicated to personal life. Self-care also took the form of self-advocacy. Esther, for instance, worked with a hostile male colleague she described as "a jerk, in general." She 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.

The women spoke of dividing the day into separate blocks of work and personal time. Dividing time this way—compartmentalizing—was their way of adapting to the ideal worker



norm. This example brings to light the incompatible intersection of women's domestic realities and the prevalent gendered standard within STEM that demands relentless dedication to scientific work (Kachchaf et al., 2015). When STEM women adapt to masculine ideals, gendered schemas about what it means to be a female or male scientist are reproduced (Hart, 2016). Were STEM institutions to accommodate women's family responsibilities, women would have options other than conforming to an adverse norm. Instead, women could choose to interweave family responsibilities with their work. For example, a new mother might bring her baby to the office and breastfeed according to the baby's needs, a mother of young children could leave the office unexpectedly to care for a sick child, and a daughter of an elderly parent could drop in to visit as needed without negative consequence. Such accommodations would also improve women's lives in other ways; for example, there might be less questioning of their dedication to work and less pressure on women to conform to an incompatible work style. Notably, such accommodations would 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 in the Forms of Funding, Resources, and Supportive Department Chairs*

Research funding gave the women freedom to find new research problems or delve more deeply into problems, work without feeling rushed, and travel. For instance, Shana's theoretical research had developed to a point that would allow new discoveries, but was difficult to fund because funding entities tend to favor experimental work. She expressed concern that were she to lose funding, her line of research would lose important momentum

and might have to begin again from scratch at some undetermined time in the future. 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; when lab space was unavailable, she felt sad, disconnected, and powerless. The women spoke of department chairs or executive level leaders who stood behind 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.

Shana operates in the contentious intersection of masculine and feminine approaches to science. On the one hand, her topic is complex and highly abstract, consistent with traditional masculine science ideals (e.g. focus on the inanimate; distant and abstract; Schiebinger, 1999). On the other hand, her research approach is more feminine--theoretical, exploratory, multidisciplinary, and collaborative--and challenges conventional epistemological paradigms. Contrary to conventional masculine empirical approaches that prevail in STEM, her research proposes new theories that have no basis in confirmed premises. STEM gatekeepers prefer models that are mathematically manipulable to the exclusion of those that emphasize global and functional interrelationships (Schiebinger, 1999); Shana's pure theoretical research, crossing multiple domains within and outside STEM, signifies the latter. Generally, STEM gatekeepers strongly prefer the traditional masculine objective epistemology of science (Keller, 1985), and research funding follows that preference. For example, the National Science Foundation's gold standard for research funding sets two main criteria for grant proposal evaluation: intellectual merit, and broader impacts of the proposed research (National Science

Foundation, 2014). Although the intellectual merit of Shana's research is widely acclaimed, the broader impacts are less evident and would be difficult to defend on grant applications that require practical justifications. Although Shana's research is feminine in its epistemology, its lack of altruistic motivation is another area of intersection with masculine science ideology.

#### Feminist Poststructuralist Discourse Analysis (FPDA) Findings

FPDA can help uncover implicit meanings in participants' narratives (Frost & Elichaooff, 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, in their interviews 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 helped reveal implicit meanings. These 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 the remarks are important), and other language structures that suggested meanings that expressed ideas other than those intended by the words alone.

#### *Shana's Masculine Epistemology*

Shana differed from the other women in her positivist philosophical approach to

scientific inquiry—she expressed the belief that the purpose of science is to move ever closer toward objective “truth.” That orientation began in childhood; she recalled feeling uneasy completing assignments that required open-ended, subjective responses. Positivism is associated with the 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:

Most discoveries start with opinion, then you predict possible answers and test them. There’s something comforting about testing the solutions and moving from opinion to something we know is true. Once something has been tested, then I can believe it’s truth and not just opinion.

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.” 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 [large city]<sup>1</sup> and that's when we got married then, at that time. And we got an apartment that was halfway between [large city] and [another large city] because I didn't know which direction I would go. And it turned out that in what I wanted to do, [small research university], in [another large city], was actually the better school. Most people just can't imagine that [small research university] would have been better than [large research university] but it really was. I went to graduate school at [small research university] and then we eventually then moved in closer there.

When she spoke of other people's perceptions of her choice, Claire's tone was tentative. Her words attempted to persuade the listener that her choice was the right one; for example, the smaller school "was actually the better school," and "most people can't imagine" that the smaller school was a better environment for 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 would have included some amount of uncertainty or doubt. She makes clear to the listener that any uncertainty or doubt was in the past and short-lived: she repeats the word "then" several

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<sup>1</sup> Specific information has been redacted to protect the anonymity of the participant.

times and places the context “at that time” in the past. Reliving the experience in her interview raised old feelings associated with the decision, and Claire implicitly communicated those emotions in her tone. In fact, at the end of the interview Claire told me, “You dredged up things that I had forgotten about a long time.” 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 in [another large city].

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 experiences in hindsight her tone communicated certainty that she had made the best decision; for instance, she takes ownership of the good decision (“I went to graduate school,” “I ended up”). Understanding the hidden uncertainty, self-doubts, and eventual triumph hidden between the lines of Claire’s story would be empowering for young STEM women going through a similar process.

#### *Esther’s Selective Resistance to 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 a sense of 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 awhile. 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.

The authenticity of Esther's 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 tended to attribute her 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 was capable of shrugging off implicit bias without serious emotional consequence. Her tone, however, was tentative as indicated by her word choices ("maybe," "I don't know," "I guess," and "it seems") and revealed more discomfort with her experiences than her words signified. For instance, she shared an example that shed more light on her feelings:

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. I'm either participating and contributing, or I'm not going to be on the committee.

As her story unfolded, Esther's feelings alternated between tolerance and vexation. She repeated her view that the biases were "not on purpose" three times. However, her nonverbal language became more earnest (leaning forward, eye contact with the interviewer) and

communicated aggravation (slight frown, hand gestures) when she spoke of her male peers' unwillingness to discuss her research. Despite her tolerance and attributing the source of bias to culture, Esther found those experiences upsetting.

The way Esther coped with workplace bias—with calm tolerance and selective confrontation of a few serious incidents—helped maintain her professional status and respect and advance her career. Nevertheless, accepting biased behaviors as “cultural” unintentionally reproduces those very norms. This is an important finding for raising awareness in the academic community of how implicit bias survives over time.

### 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 child care. 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 gender assigned at birth, the women occupied multiple contextual positions that interacted, varied across contexts, and changed over time. However, research on women in STEM tends to view women as a homogeneous group of individuals with similar needs and obstacles, and treat genders 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 in the "double bind," or who are marginalized in more than one way--for instance, women who are lesbian or transgender, are ethnic minorities, have a physical disability, or who interrupt the tenure clock to care for family.

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 contexts such as 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.

Finally, there is a need for further examination of women's success from qualitative, feminist perspectives (Mullet, Rinn, & Kettler, in press). 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 along several dimensions, including (a) triangulation of analytical methods (thematic analysis and FPDA), (b) thick description of the findings, and (c) reflexivity, or the investigator's ongoing recursive process of reflection on theoretical bases that inform the study. The well-being of participants was protected by adhering to guidelines for ethical human subjects research; 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 of higher education), the findings are specific to the study's participants and context and cannot be generalized in a broad sense. The interviews were limited to 60-90 minutes in length to respect the time constraints of the participants; this population of elite women was difficult to access because of the multiple demands on their time. Ideally, the data would include a short follow up interview to share and discuss the overall findings with each participant. 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.

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

*Major Themes across the Interviews*

Themes	Subthemes
The women shared many traits, motivations and approaches to thinking and working.	<p>Personal traits: openness, agreeableness, persistence, and high self-confidence.</p> <p>Motivations: intrinsic goals, collaboration, and altruism.</p> <p>Approaches to thinking and working: a creative or innovative thinking style, interdisciplinary perspective on problem solving.</p>
The women’s early STEM experiences were similar, but their paths diverged through the beginning and early stages of their academic careers.	<p>Early support and encouragement from adults or older children.</p> <p>Access to high quality or alternative education.</p> <p>Critical decisions were driven by either their women’s interests or family concerns.</p>
The women recognized the need to balance the work and life, and actively and consistently engaged in self-care.	<p>Physical activity and exercise.</p> <p>Time-saving strategies.</p>

Themes	Subthemes
	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

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## CATALYSTS OF WOMEN'S TALENT DEVELOPMENT IN STEM: A SYSTEMATIC REVIEW

After decades of efforts to bring about gender parity, a still disproportionately small number of women persist to the highest levels of academic science, technology, engineering, and mathematics (STEM). Although numbers of women in the physical sciences, mathematics, and engineering are growing, women are still far outnumbered by men especially at the upper levels of those disciplines (Hill, Corbett, & St. Rose, 2010). The number of women who earn doctorates in STEM fields has grown in recent years; for instance, in 2012 in the United States, women earned 46% of all doctorates of which 41% were in science and engineering fields (NSF, 2015a). Although women enter science and engineering at nearly the same rate as men, the National Science Foundation designates physics, computer science, mathematics and engineering “low participation” fields for women: in 2012, women earned only 20% of physics doctorates, 20% of computer science doctorates, 24% of doctorates in math and statistics, and 23% of engineering doctorates (NSF, 2015b).

Women in academic employment continue to differ from their male counterparts in rank and tenure. Although the number of women with doctorates in science and engineering who also hold full professorships has doubled since 1993, those women still occupy less than one-fourth of senior faculty positions at research-intensive academic institutions (NSF, 2015b). Further, women are still severely underrepresented among Nobel Prize recipients. Despite Marie Curie's heroic start, between 1903 and 2015 only 48 of 870 Nobel recipients were women. In chemistry, four of 171 recipients were women, and although women earn 20% of the doctorates in physics, only 1% of Nobel Prizes in Physics have been awarded to women (“Nobel,” 2016). The strikingly low representation of women among Nobel Prize recipients

indicates that women are not achieving eminence in numbers proportionate either to men or to their overall representation in STEM.

The demand for scientists in growing sectors of the economy such as technology and engineering is intense and cannot be met without including both men and women (Corbett & Hill, 2015). Women scientists bring diversity to the scientific community, and increased diversity has positive implications for science. For instance, Rosser (1987) pointed out that feminist approaches challenge prevailing scientific thought and may yield information that provides a more complete picture of scientific phenomena. Including the thoughts and ideas of “the other half” of our population adds more possibilities for the production of useful, creative, or innovative ideas that may not otherwise make their way forward.

Much research on women in STEM has examined obstacles and barriers that contribute to women’s attrition from STEM. For instance, women’s attrition from STEM has been ascribed to beliefs that men are innately better suited to STEM fields (Hill et al., 2010), females’ lack of interest in STEM (Heilbronner, 2013), implicit gender bias in STEM work settings (Hewlett, 2008; Kost-Smith, Pollock, & Finkelstein, 2010), discrimination against females in academic review and selection processes (Chesler, Barabino, Bhatia, & Richards-Kortum, 2010), differences in women’s ways of working (Hewlett, 2008), and challenges surrounding work-life balance (Herman, 2015). Thus, although we know much about why women leave STEM, we know relatively little about why some women stay in STEM and succeed at the highest levels. Few studies have examined catalysts that contribute to their persistence and achievement at the highest levels in male-dominated disciplines. The current study is a systematic review of the literature focused on factors that catalyze the success of women who reach elite levels (for

example full professorships, academic leadership positions, or international recognition) of talent development in STEM.

### Purpose and Research Questions

The purpose of the study is to critically examine the literature on women's success at elite levels in academic STEM. This study approaches the topic from a growth perspective by examining what catalyzes STEM success for women who are highly capable or have developed extraordinary talent in STEM. The following research questions guided the review:

- What catalyzes the academic and professional success of females who achieve exceptional levels of talent in academic STEM?
- What research approaches and frameworks have been used to explore successful women's STEM talent development?

### Definitions

*STEM* is defined for the purposes of this study to include only highly male-dominated disciplines where the highest levels of achievement are disproportionately underrepresented by women. Those disciplines include physical sciences (physics, chemistry), technology (computer science), engineering, and mathematics. Both applied and research sciences are included in the definition. We operationalize *talent* as a domain-specific set of capabilities and potentialities that evolve and develop over time (Bloom, 1983; Gagne, 2003; Reis, 2005); here, the domains of focus comprise the STEM domains. In the current study, *success* is defined as exceptional STEM talent; in other words, a set of STEM-specific capabilities developed to levels that enable



achievements considered outstanding relative to a group of peers such as practicing scientists in a discipline or academic cohort.

## Method

This systematic review of literature is organized around the PRISMA protocol. PRISMA is a set of evidence-based items that define accepted practices for conducting systematic reviews and meta-analyses (Moher, Liberati, Tetzlaff, & Altman, 2009).

### Eligibility Criteria

Eligible studies were limited to scholarly, peer-reviewed manuscripts published in English after 1990, or the period following the end of second-wave feminism in the United States. Publication types included empirical research, meta-analyses, and systematic reviews published in scholarly academic journals. Due to the focus on peer-reviewed empirical research, dissertations, editorials, monographs, and manuscripts published in praxis-oriented journals (for example, *Gifted Child Today*) were ineligible.

### Data Sources

Data sources were electronic databases covering the areas of education, gender studies, psychology, and social sciences. The specific databases included Academic Search Complete, Education Source, ERIC, Gender Studies Database, Professional Development Collection, PsycINFO, and SAGE Journals Online.

### Search and Selection

In each database, an initial search was performed against article abstracts using the Boolean search term *“women OR female” AND “science OR STEM” AND “gifted OR talent.”* Whenever possible, search limiters were used to align the initial search results more closely with the eligibility criteria. For instance, many databases allow limiting the search to only peer-reviewed publications or to a specific date range. The search concluded in August 2016. Initial search results are summarized in Table 3.

### Screening

The selection process is diagrammed in Figure 3. Screening criteria shown in Table 4 guided selection of articles from the initial list of studies for possible inclusion. First, studies published in English between 1990 and 2016 were retained. Second, studies published in scholarly journals were retained; those published in non-indexed or predatory journals, trade journals, magazines, or newspapers were rejected. Cabell’s International and Beall’s List were consulted to determine the indexing and predatory status, respectively. Fourth, studies reporting research conducted in North America or Europe were retained. This limitation was enacted because gender roles and the dynamics of gender bias are particular to cultures. North America and Europe were selected for their shared scientific heritage (Lindberg, 2008) and similar gender perspectives on science (Nosek et al., 2009); those similarities allow comparison of findings across the articles, and also provide a degree of transferability of overall thematic findings from this review. Fifth, because the current study focuses on catalysts of women’s success in STEM, only studies of successful women in academic or professional STEM were retained. Sixth, only empirical studies (qualitative, quantitative, and mixed-methods), meta-

analyses, secondary data analyses, and systematic reviews were retained; non-systematic reviews, editorials, and monographs were rejected. Finally, articles that aligned with the current study's focus (catalysts leading to women's success in STEM) and research questions were retained. Twenty articles were retained after screening.

### Quality Evaluation

To assess the quality of the included articles, each was judged on the nine quality criteria shown in the quality rubric designed specifically for this study (Table 5). Each criterion was evaluated on a 4-point scale where 3 = *exemplary*, 2 = *acceptable*, 1 = *poor*, and 0 = *unacceptable*. The total score for each article was calculated by summing the scores over the nine dimensions. Possible scores ranged from 0 to 27. "Poor" and "Inadequate" articles, or those with overall scores less than or equal to 9 were excluded. After the quality assessment, the final data corpus comprised 18 articles.

### Data Collection

The extraction protocol shown in Table 6 guided data extraction from the retained articles. Data extracts included research purpose, country where the research was conducted, participant characteristics, description of context or setting, research design, theoretical or conceptual frameworks used in the research, and key findings. Extracted data were stored in a database indexed by article. Additionally, complete Findings or Results, Discussion, and Conclusions sections of each article were extracted and stored in a database for more in-depth analysis. Both databases are available from the authors upon request.

## Analysis

First, summary data were inspected for patterns or trends across each extracted variable and over time. Next, the Findings or Results, Discussion, and Conclusions sections of the articles were analyzed using thematic analysis, a qualitative data reduction method for identifying patterns or themes within data (Braun & Clarke, 2006). Thematic analysis proceeds through six steps. The first step involves immersion in the data; immersion took place during the screening, quality assessment and data extraction processes. The second and third steps entail generating codes and searching for themes. In these steps the Findings or Results, Discussion, and Conclusions sections of each article were coded using an inductive coding procedure. Inductive coding is appropriate for condensing raw data into a summary format and for developing a model of meanings derived from the raw data, and produces a small number of summary categories that capture important categories of meaning identified in the raw data (Thomas, 2006). To generate codes, the investigator read each data item line-by-line, marking meaningful text segments (usually sentence in length) with a unique identifier. Each text segment was assigned a category label; text segments that did not fit an existing category label were assigned a new label. Each category label represented a unique preliminary theme. During the coding process, each text segment was entered verbatim in a database indexed by article, unique identifier of the text segment, and its category label; the database is available from the authors on request. At the conclusion of this step, there were 560 text segments in 21 preliminary categories shown in Table 8.

The fourth, fifth, and sixth steps in thematic analysis involve revising the preliminary categories, defining broad themes, and producing a descriptive account of the themes. A theme

“captures something important about the data in relation to the research questions” (Braun & Clarke, 2006, p. 82). Preliminary categories that appeared in at least three articles were retained (see Table 8). To define themes, the investigator further revised the retained categories by combining categories or eliminating categories that lacked meaning or relevance.

## Results

Data extracted from the reviewed articles are summarized in Table 7. Thematic analysis produced four major themes, which are summarized and described in Table 9 and described here in depth.

### Talented Women Who Succeed In STEM Share Similar Personal Characteristics, Values, Perceptions, and Choices

#### *Personal Characteristics*

Females with exceptional STEM talent share cognitive, affective, and conative profiles consistent with previously identified characteristics of exceptional male scientists; for example, STEM-talented women show pronounced quantitative reasoning, scientific interests, remarkable energy, and a clear preference for coursework in science and math (Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001). Women who persist in STEM doctoral programs and professions are independent, confident, high achievers with family responsibilities (Herzig, 2004) who emphasize the need to focus on their careers in order to achieve success (Tirri & Koro-Ljungberg, 2002). STEM-talented college women are serious about their studies, competitive in nature, perfectionistic, determined, and driven to learn and understand their subject (Gavin, 1996). Although STEM-talented men and women have similar

math ability, women have more balanced ability profiles than similarly talented males, and are less oriented toward STEM education and professions (Lubinski et al., 2001; Webb, Lubinski, & Benbow, 2002). For instance, mathematically talented women tend to be more verbally talented than men of similar math ability and gravitate toward fields that draw heavily on verbal ability (Webb et al., 2002).

STEM-talented women are similar to STEM-talented men in age of first publication, age at which STEM talent was first recognized, and age of PhD; however, women publish less frequently than men and women's publications are less likely to be cited by peers (Feist, 2006). In general, women who are exceptionally talented in STEM tend to be first or second generation Americans (Feist, 2006) with parents who hold a bachelor's degree or less (Dabney & Tai, 2014). However, parents of women of color complete education beyond the bachelor's degree (Gavin, 1996).

### *STEM Readiness*

Strong pre-college and undergraduate experiences help women build STEM competencies that are recognized by others, and that recognition in turn helps women persist in STEM and develop strong STEM identities (Carlone & Johnson, 2007; Herzig, 2004). College women who succeed as math majors have both math ability and interest that were recognized in childhood (Gavin, 1996). Successful college STEM women's interest in science prior to the fifth grade is equivalent to interest that developed after the fifth grade (Dabney & Tai, 2014). However, women know later in their lives that they want to pursue STEM than men do, and become aware of their STEM aptitude at a later age than men do (Feist, 2006). Successful

college STEM women participated in gifted and talented programs, honors or advanced academics, or International Baccalaureate prior to college; many took four years of math during high school, and the majority took calculus (Gavin, 1996). Early positive academic experiences influence women's later academic and career direction and outcomes; for instance, female chemists report higher grades and better experiences in secondary and undergraduate chemistry courses, whereas female physicists report better grades and experiences specifically in their physics courses (Dabney & Tai, 2014). However, not all women in STEM graduate study begin with equal skills and knowledge about the practice (Herzig, 2004). For example, some women of color engineering majors have naïve understandings of their field and the nature of the engineering practice because engineering concepts and career exploration were never introduced prior to college (Tate & Linn, 2005). Even with strong preparation and interest in science, women of color in STEM encounter difficulties when they encounter the meritocratic culture of science (Carlone & Johnson, 2007).

### *Interest in STEM*

Talented STEM women are interested in science because it matches their aptitudes, is aesthetically appealing, or because they like its logical and rigorous nature (Feist, 2006). Gifted female scientists prize their intellectual lives and are attracted to problems and methodologies associated with science work (Subotnik & Arnold, 1995). Talented women in STEM are more interested in maintaining research as part of their professional lives relative to talented men in STEM and talented men and women in non-STEM fields (Subotnik, Stone, & Steiner, 2001).

Successful STEM women associate their interest in science with altruistic career goals (Carlone & Johnson, 2007). STEM women attribute their interest in STEM to its potential for solving important problems, helping humanity, or because it satisfies their curiosity about the world (Feist, 2006). Women scientists' altruistic values may play a role in male-female disparities in STEM career outcomes (Webb et al., 2002). STEM-talented women gravitate toward disciplines that allow contact with people (Lubinski et al., 2001); for instance, women are more likely to pursue a career in the social or life sciences than in the physical sciences (Feist, 2006). Academic choices made by women and men may reflect an "organic-inorganic distinction" (p. 791) where women are more likely to earn degrees in the humanities and life sciences, while men are more likely to earn degrees in math or physical sciences (Webb et al., 2002).

Science-talented women are intrinsically interested in science, need no external support for maintaining their science interest, and maintain their interest in spite of discouragement (Carlone & Johnson, 2007). However, talented college women who leave STEM cite a change of interest as the reason for their decision to pursue a non-STEM major (Webb et al., 2002). Given that preference profiles stabilize in adolescence and predict sex differences in professional and educational outcomes in adulthood (Lubinski et al., 2001), early emphasis on the relationship between altruism and science could encourage more women to pursue research science (Carlone & Johnson, 2007).

Successful women in STEM share a love of challenge and problem solving (Subotnik & Arnold, 1995; Tate & Linn, 2005; Tirri & Koro-Ljungberg, 2002); for many, the most satisfying aspects of their professional lives centers around problem solving and the satisfaction gained



from resolving intellectually challenging problems (Subotnik & Arnold, 1995). Gifted female scientists prize their intellectual lives and are attracted to problems and methodologies associated with science work (Subotnik & Arnold, 1995). These women's enjoyment of challenge, confidence in their abilities, and preference for competition contributes to their choice to major in STEM (Gavin, 1996). Some STEM women, however, dislike the abstractness in higher level courses, and prefer practical learning activities to which they can relate (Gavin, 1996).

### *Persistence and Resilience*

Although being female increases the odds of leaving a STEM major (George-Jackson, 2014), successful female scientists are resilient and show remarkable persistence (Tirri & Koro-Ljungberg, 2002). Women work hard for their success in STEM (Gavin, 1996); they persist despite hardships and reaffirm their abilities and talents despite obstacles (Charleston, George, Jackson, Berhanu, & Amechi, 2014). Persistence is evident in their strong goal and task orientation; for example, women who reach the highest tiers of STEM are more likely to have taken advantage of opportunities to gain international experience or training (Tirri & Koro-Ljungberg, 2002). However, persistence for women in STEM depends on successful negotiation of disparate communities such as family, work, and the larger cultural group (Herzig, 2004). For instance, successful women of color persist in a culture of science that researchers consider masculine and White (Carlone & Johnson, 2007) despite isolation, lack of recognition of their potential, and lack of social support from male peers (Charleston et al., 2014). Women scholars

who stay in STEM do so despite failures of others to recognize their potential; their persistence is a testament to their ability to adapt and evolve their own identity (Carlone & Johnson, 2007).

### *STEM Identity*

For successful women, a strong STEM identity embodies STEM competence, performance, and recognition by the self and others as having potential to excel in STEM (Carlone & Johnson, 2007). Gifted female scientists build the roots of STEM identity in their childhoods (Tirri & Koro-Ljungberg, 2002). Without a positive vision of the self as a scientist, women may be unwilling or unable to incorporate STEM in their futures (Buday, Stake, & Peterson, 2012). STEM-talented women's own perceptions of their future STEM career seem to override the opinions of others in determining their interest and motivation for a STEM career (Buday et al., 2012). For instance, women's altruistic perspective on science helps create a space for them in science, which in turn helps them view themselves as scientists (Carlone & Johnson, 2007). Highly successful female scientists manage to combine their notion of feminine identity with their notion of academic ability (Tirri & Koro-Ljungberg, 2002), recognize themselves as a "science person," and express enthusiasm for science (Carlone & Johnson, 2007). Because STEM women are counter-stereotypic exemplars, the salience of their own success may mitigate implicit gender-STEM stereotypes (Smeding, 2012). Being a successful outsider helps talented female STEM students develop strong implicit self-STEM associations, and those positive associations in turn help them resist the influence of stereotypes on their performance (Smeding, 2012).

Feminine STEM identity and roles in academia are culturally dependent and difficult to categorize under fixed labels such as “traditional” or “feminist” (Tirri & Koro-Ljungberg, 2002). Women are not free to develop any given STEM identity; instead, their choices are shaped by larger meanings of “scientist” derived from the sociohistorical legacy of science and the political meanings of being a woman in STEM (Carlone & Johnson, 2007). Viewed from a broader sociocultural perspective, women’s STEM identities are emerging, contingent on context, and fragile, but become stable when habitually accessed, performed, and recognized by others across time and contexts (Carlone & Johnson, 2007). For instance, a woman’s vision of the self in a STEM career is closely tied to social and environmental supports for her STEM career (Buday et al., 2012).

The “double bind” refers to the additional challenges minority women in STEM face as they experience the intersection of sexism and racism in their STEM careers (Malcolm, Hall, & Brown, 1976). Race and gender are virtually inseparable and confluent in the lives of STEM women of color (Charleston et al., 2014). For instance, Black women struggle with their identity as women of color in the racially and sexually exclusive field of computer science where, depending on the situational context, they identify either as Black, female, or both (Charleston et al., 2014). Some Black STEM women are unable to separate their identities as Black and female and may find it difficult to ascertain whether they are treated a certain way because they are Black or a woman (Charleston et al., 2014). Further, women of color find it more difficult to develop a strong STEM identity than White women do; racism may have been operating at critical points in their academic lives, such as times when they were bidding for recognition as STEM students or early career research scientists (Carlone & Johnson, 2007).

Academic success anchors STEM identity for women of color (Tate & Linn, 2005). For example, successful women of color engineering majors demonstrate strong academic identities and stay on track to complete their programs (Tate & Linn, 2005).

Social identities of women in STEM may be critical to their professional (Talves, 2015) and academic (Tate & Linn, 2005) success. For example, women of color who aspire to engineering careers may exclude themselves from their perceptions of engineers as a social group (Tate & Linn, 2005). Similarly, a student who feels like an outsider in her engineering environment may have difficulty forming the study groups that are necessary to enhance her academic performance (Tate & Linn, 2005). To counter the feeling of being an outsider in their disciplines, some STEM women minimize their female identities; suppressing their female identity prevents others in the field from associating them with traditionally feminine values and responsibilities, such as child care (Talves, 2015).

### *Values and Beliefs*

Women scientists' deep beliefs and values, rather than interest in science, shape their academic and professional goals (Carlone & Johnson, 2007; Subotnik & Arnold, 1995). College STEM women make demands on themselves to excel academically, challenge themselves, and compete (Tirri & Koro-Ljungberg, 2002), but also expect personal satisfaction from their courses and college experiences (Gavin, 1996). STEM women place a high value on the intrinsic rewards of a job, such as satisfaction and respect among colleagues (Ferriman, Lubinski, & Benbow, 2009); external values and expectations, such as their academic department's values, are secondary (Carlone & Johnson, 2007). For college STEM women, high grades are less important

than achieving a true and complete understanding of their content (Gavin, 1996). Further, STEM women place value on having a part time career, having close friendships, giving back to the community, and living close to family (Ferriman et al., 2009).

The need for relevance is a recurring theme in college STEM women's experiences. Personal relevance promotes women's positive self-concept, and practical relevance gives meaning and purpose to their endeavors in STEM (Gavin, 1996). Successful STEM women are more holistic and communal in their orientation toward life, more focused on social well-being relative to male counterparts (Ferriman et al., 2009) and express motivation to serve people rather than to gain status or wealth (Carlone & Johnson, 2007). STEM women prefer to spread their commitments over work, friends, family, and community (Ferriman et al., 2009).

### *Perceptions*

Among women who love science and emerge at the top of a long, competitive educational process, only a few believe it possible to reach elite tiers in STEM (Subotnik & Arnold, 1995). STEM-talented women recognize their own abilities and want to capitalize on those abilities to reach their full potential (Gavin, 1996), but question whether success in science results from talent and creativity, or from politics and self-promotion (Subotnik & Arnold, 1995). STEM women believe setbacks and lack of progress are related to their own personality or ability rather than to the interruptions of having children or family, and either trivialize their achievements or attribute them to others (Talves, 2015). For example, college STEM women often abstain from volunteering answers or asking questions in class (Gavin, 1996). Although women scientists of high rank feel that they have influence in the context of

their work lives, their job satisfaction is still similar to that of women in lower ranks (Settles et al., 2006). In terms of environment, college women in STEM prefer smaller classrooms (Dabney & Tai, 2014) and structured academic programs that extend beyond lower division coursework, and believe that structured programs help sustain their positive STEM self-concept (Tate & Linn, 2005).

### *Choices*

Narrowly focused research studies tend to ignore the personal life sacrifices that women scientists make to do scientific work, or the extraordinary management work they do to coordinate the demands of two institutions that do not blend well. Women scientists endure costs in terms of sleep loss, loss of leisure time, and stress in order to make their scientific pursuits possible (Herzig, 2004). Eminent female scientists make compromises related to their science identities, usually concerning career choice; those compromises, however, do not prevent them from developing their talents (Tirri & Koro-Ljungberg, 2002). While talented women are reluctant to give up personal relationships, recreation, or time alone for a future goal that might not have a clear payoff, they are willing to make substantial sacrifices if they are confident those sacrifices will support their research over time (Subotnik & Arnold, 1995). For example, women scientists who remain in academia tend to seek out positions in small teaching colleges rather than in large research universities (Herzig, 2004).

Women with the talent and passion to work long hours to succeed in STEM change may change their priorities after becoming parents; with motherhood, they seek reductions in work hours, take temporary leaves of absence, or become homemakers (Ferriman et al., 2009). For

STEM women with children, access to affordable child care, opportunities for part-time work and study, flexible deadlines, and financial support can mitigate issues associated with balancing research and raising a family (Herzig, 2004). Talented women in countries with progressive social policies (for example, a long, well-paid maternity leave) can put their academic careers on hold without fear of losing their jobs or achievements (Tirri & Koro-Ljungberg, 2002), but progressive social policies are lacking in many Western countries. Some successful female scientists spend money on outside help for their home (for example gardeners, nannies, or housekeepers), allowing them to divide more time between work and family (Tirri & Koro-Ljungberg, 2002). The women also make choices that maintain and support their psychological and physical needs. For instance, female scientists practice psychological self-care by speaking up for their rights when treated unfairly (Tirri & Koro-Ljungberg, 2002), by taking action to make their unrecognized potential known (Gavin, 1996), or by maintaining good health by taking time to exercise and eat healthfully (Tirri & Koro-Ljungberg, 2002). For example, women who were not placed in the highest math class at some point in high school fought the placement, and as a result were moved to honors or advanced classes (Gavin, 1996).

Values and beliefs play an important role in women scientists' academic and professional choices; one female physicist remarked, "I have made my choices according to those values I find important" (Tirri & Koro-Ljungberg, 2002, p. 158). Women's academic and career choices appear to reflect an "organic-inorganic distinction" (p. 791) by which women are more likely to pursue humanities or life sciences, while men are more likely to pursue math or physical sciences (Webb et al., 2002). STEM-talented women view their role in the field as a scientist with an altruistic focus (Carlone & Johnson, 2007), and perhaps for that reason are

more likely to change from STEM to a non-STEM discipline than their male counterparts (Feist, 2006). In terms of career choice, STEM talented college women tend to choose majors that mirror their overall ability patterns (Webb et al., 2002). Female STEM graduate students self-select opportunities for developing STEM talent early in their lives, and that process intensifies as they mature (Lubinski et al., 2001). For example, STEM college women who self-identify as research scientists align their actions and energy with more experienced scientists by maintaining an involvement in research activity throughout their studies (Carlone & Johnson, 2007). Secondary and postsecondary academic achievement and experiences also play a role in women's choice of STEM field; for example, prior negative academic experiences in physics and positive experiences in chemistry differentiated women into the field of chemistry (Dabney & Tai, 2014).

#### Positive Social Interactions with Family, Peers, and Meaningful Others Catalyze Women's Success at High Levels of STEM

##### *Mentoring and Recognition*

Talented STEM women seek mentors more actively, and are identified more frequently by mentors as possible protégés (Subotnik et al., 2001). Encouragement from mentors in graduate school plays an important role in STEM women's persistence; for instance, female mathematics students who had doubts about continuing stayed when they were encouraged by their advisors (Herzig, 2004). Mentors who are influential in women's decisions to major in STEM are female, enthusiastic about STEM, encourage questions, and treat their mentees with respect (Gavin, 1996). For women in STEM, mentors' encouragement and support were helpful in making their decision to attend graduate school (Herzig, 2004).



Mentors' personal interest in their female students' STEM success nurtures and encourages persistence (Gavin, 1996; Herzig, 2004). For instance, the intervention of a teacher affirming women's aptitude for mathematics is crucial in nurturing their enjoyment of math and their persistence in math courses--women need to be told they are talented in math and that they should continue to pursue it (Gavin, 1996). Moreover, a professor's encouragement can be the deciding factor in a woman's choice of major; for example, a professor's explicit recognition of women's STEM aptitude and encouragement to continue influenced women's decisions to major in STEM (Gavin, 1996).

College STEM women who have not acquired the necessary political knowledge and strategies depend on academic advisors to help them learn those strategies (Herzig, 2004). However, mentors at the graduate and early career stages tend to seek protégés who can enhance the mentor's work (Subotnik & Arnold, 1995). Regrettably, few women STEM researchers are available in graduate and professional environments to serve as mentors (Subotnik & Arnold, 1995). The small numbers of women STEM faculty and the need for female faculty to mentor same-sex students create a shortage of suitable mentors (Herzig, 2004); the shortage could be addressed by rewarding senior women who choose to mentor junior women (Subotnik & Arnold, 1995).

Recognition is a concept that helps make sense of the distinctive experiences and meanings for women in STEM, and serves as a framework for understanding interactions between women's gender, race, ethnicity, and STEM identity (Carlone & Johnson, 2007). Throughout the process of socialization into applied and research STEM fields, talented women derive recognition from many sources, including teachers, administrators, academic awards,

invitations to speak, publications, and positive feedback from peers and professors (Carlone & Johnson, 2007; Subotnik & Arnold, 1995). Successful STEM women are recognized by peers, teachers, and themselves during elementary and secondary school for exceptional math achievement and for being top students in their class (Gavin, 1996). For STEM women, early recognition of STEM talent by others predicts early publications, which in turn predicts lifetime productivity (Feist, 2006).

Encouraging feedback keeps eminent female scientists focused and interested despite obstacles (Tirri & Koro-Ljungberg, 2002) and shapes women's own identities as scientists (Carlone & Johnson, 2007). For example, one female doctoral student majoring in molecular biology became recognized in several environmental biology labs as a molecular specialist; that recognition helped her view herself as a content specialist in her field (Carlone & Johnson, 2007). Recognition can be problematic for women of color in STEM because it hinges critically on an external audience composed primarily of White males (Carlone & Johnson, 2007). However, successful women of color in STEM are able to locate professors and mentors who recognize their STEM talent and help them integrate into their community of practice; it is then within the community of practice that these women develop their STEM talent (Carlone & Johnson, 2007). Women's altruistic orientation may protect them from lack of external recognition; STEM women who are committed to serving others depend more on recognition from people who would benefit from their altruistic commitments than on recognition from people of stature in their fields (Carlone & Johnson, 2007).

### *Social Support*

Social support from professors, peers, and family contributes to women's positive vision of self in a STEM career (Buday et al., 2012). Family, friends, and social well-being outside STEM are important factors for successful young female scientists (Ferriman et al., 2009). Early parental support plays an important role in women's later persistence in STEM; for example, parents of successful STEM women were supportive of their decision to pursue STEM and gave verbal support for their daughters' competence and self-advocacy (Gavin, 1996). Women who persist in STEM may benefit from early counter-stereotypical family socialization environments, suggesting that processes other than professional and academic context explanations may be at work (Smeding, 2012). Early in their careers, intimate relationships can act either as brakes or supports to STEM women's continuing professional achievement (Subotnik & Arnold, 1995). For instance, moral support from a significant other enhances doctoral persistence for STEM women (Herzig, 2004), and a supportive spouse is the most important choice in the lives of many eminent STEM women (Tirri & Koro-Ljungberg, 2002).

Perceptions of a supportive social environment lead to women's positive beliefs about future success in a STEM career and influence women's motivation to pursue a STEM career (Buday et al., 2012). Although successful women in STEM view themselves as autonomous and independent, they value connections with members of the STEM community and believe that connections with others in their field are important both for political value and for accomplishing productive work (Herzig, 2004). Power struggles do, however, exist between STEM women, and women are aware that not all mentors and advisors are supportive (Subotnik & Arnold, 1995). For instance, established women scientists may arrogate superior

positions over other women based on differences in age, academic position, or experience; unfortunately, such positioning strategies reproduce gendered power structures in STEM (Talves, 2015).

Social and academic peer support and encouragement are particularly important for women who are members of another underrepresented group in STEM (Herzig, 2004; Tate & Linn, 2005). In social contexts outside STEM, women of color possess well-developed social identities; yet, in academic contexts, they feel plagued by feelings of difference and of not belonging (Tate & Linn, 2005). For instance, although women of color persist successfully in their engineering majors, they feel separate from STEM, like “outsiders within” (Tate & Linn, 2005, p. 490). However, graduate women who form supportive peer relationships learn and complete coursework together, share information, and provide one another with moral support (Herzig, 2004).

#### Supportive Institutional Characteristics Catalyze Women’s STEM Talent Development

Institutional support contributes directly to women’s ability to envision themselves in STEM careers (Buday et al., 2012). Features of STEM institutions that contribute to women’s persistence include support for women with families, departmental or program structure, the institution’s epistemological standpoint, and financial support (Herzig, 2004). Male-dominated STEM adheres to a relentless professional clock, but if institutions were to welcome women back after intense periods of family care, more women would persist (Subotnik & Arnold, 1995). Opportunities such as job sharing, extended paid family leave, and delaying the tenure clock have been successful in other fields such as medicine (Subotnik & Arnold, 1995). However, part-

time status and leave of absence options make it difficult for women to stay at the leading edge of their STEM careers because knowledge in STEM disciplines is less durable than in other fields: theoretical and technical knowledge turnover rates are higher in STEM than in other fields such as social sciences or humanities (Ferriman et al., 2009). Nonetheless, job security and funding must be in place for women who seek to balance STEM, committed relationships, and childrearing (Subotnik & Arnold, 1995). Women agree that some institutional factors are more discipline-specific than related to gender; for instance, some fields such as technology and computing involve working late hours, yet allow more freedom and autonomy in daily life by allowing women flexibility in when to schedule work and leisure time (Charleston et al., 2014). From an epistemological perspective, women persist and succeed in STEM institutions where they are free to play with relationships between and interactions among ideas (Herzig, 2004).

Institutional climate is a vital consideration for understanding underrepresented groups in STEM (Charleston et al., 2014). Women's perceptions of a positive or supportive STEM departmental climate are related to higher levels of job satisfaction and productivity (Settles, Cortina, Malley, & Steward, 2006). The inhospitable nature of STEM, particularly in predominately White institutions, is particularly detrimental to women; more intensive efforts to ensure equitable, inclusive environments are warranted (Charleston et al., 2014).

Policymakers and administrators can improve women's experiences in academic STEM by minimizing or eliminating obstacles to their full participation in STEM departmental academic and social communities (Herzig, 2004). It is also important to increase diversity among faculty and students in STEM institutions; broadening diversity helps mitigate hostile climates that

women describe as isolating or insensitive (Charleston et al., 2014). Additionally, higher education administrators can make STEM more hospitable by instituting periodic checks on women faculty's satisfaction and experiences with their department leaders and fellows (Settles et al., 2006). Finally, effective department leaders hold the power to create a positive climate for women STEM faculty; effective leaders can use their power to protect women's interests (Settles et al., 2006).

From women's perspectives, STEM education is relevant when it has a curriculum connected to the real world and a learning environment supportive of conjecture (Gavin, 1996). Negative classroom experiences may deter women from pursuing advanced degrees in STEM, whereas positive experiences and academic access encourage women to enter the field (Dabney & Tai, 2014). One-size-fits-all approaches to intervention programs may fail to meet the educational needs of women in STEM; effective interventions are those tailored for women in specific STEM disciplines (George-Jackson, 2014). Placing the focus on learning makes curricula and instruction more relevant to female STEM students (Gavin, 1996). An example of a learning-focused program is one that is both responsive to differential learning rates and values academic achievement; such programs promote the development of extraordinary STEM talent for women (Lubinski et al., 2001).

A key to retaining female students in graduate level STEM is to enable their active participation in their field's authentic practices (Herzig, 2004). Unfortunately, the common practice in some fields, such as mathematics, isolates students from authentic practice and thereby limits the types of relationships students are likely to develop with faculty (Herzig, 2004). Most undergraduate STEM education takes place in classes with large student-teacher

ratios or in unstructured lab environments (Subotnik et al., 2001). Well-designed programs that present personally relevant engineering problems can promote and develop students' understandings of engineering concepts and practice (Tate & Linn, 2005). For early and mid-career STEM women, opportunities such as post-doctoral fellowships can be of particular advantage, especially for women who are geographically constrained by family or resuming full time work after intense childrearing (Subotnik & Arnold, 1995).

Increasing educational programming alone is insufficient to reinforce women's persistence in STEM; persistence also depends on institution-level social supports for STEM education and careers (Buday et al., 2012). Such supports at the institutional level enhance women's integration into male-dominated departments and disciplinary academic communities (Herzig, 2004). For example, female STEM students act independently only when they feel safety and a sense of belonging, while those who lack safety and belonging have difficulty acting autonomously (Herzig, 2004). Institutional support can take the form of student support groups for women; such groups provide a safe place where they can reflect on negative experiences, practice self-care, and develop healthy responses (Charleston et al., 2014). Women of color in STEM, in particular, benefit from programs with emotional and psychological supports that promote positive social identity (Tate & Linn, 2005). Leadership provided by department chairs also appears to be an important factor in improving STEM women's outcomes; for instance, effective chairs encourage collegiality among faculty, ensure gender equity in assignments, and discourage sexist behaviors (Settles et al., 2006).

## Successful STEM Women Resist Culturally Reproduced Masculine Norms and Ideologies through Personal Agency and Cultural Production

Despite strong interest and preparation in STEM, talented women have trouble when they encounter the masculine, meritocratic culture of science (Carlone & Johnson, 2007). Masculine-gendered norms in STEM education provide male students increased opportunities for relationships with faculty, and enhance male students' sense of belonging; denied the same opportunities, female students feel less accepted and find it more difficult to act autonomously (Herzig, 2004). Black women recognize that others' misperceptions of their academic and intellectual abilities are driven by their identity as Black women and are aware of social stereotypes surrounding being a Black woman in STEM (Charleston et al., 2014). For instance, one woman explained, "There are often assumptions that I am supposed to act a certain way because I am a Black woman" (Charleston et al., 2014). Women of color whose religious beliefs contradict the objectivist norms of science are triply bound; for example, some Native American cultures hold taboos against dissection, especially during pregnancy (Carlone & Johnson, 2007). For instance, when one Native American molecular biology student escalated her case for alternatives to dissection her Dean intervened, but her lab coordinator refused to comply; instead, the lab coordinator suggested that she change her major (Carlone & Johnson, 2007). The reproduction of masculine norms in STEM, however, is not the fault of men alone; some STEM women deny a gender aspect by placing family-oriented STEM women in a negative light (Talves, 2015). For example, some STEM women express beliefs that family-oriented women cannot have both a STEM career and family simultaneously, and would be better suited to a non-STEM profession (Talves, 2015). Recognition itself is a mechanism for reproducing the status quo in STEM; individuals whose appearance and behaviors align with historical and



prototypical norms associated with “scientist” are more likely to be recognized (Carlone & Johnson, 2007). Thus for STEM women and STEM women of color, recognition of their STEM potential is complicated by the institutional and historical meanings of what it means to be a scientist (Carlone & Johnson, 2007). Further, the norms and criteria for scientific credibility shift with context; for instance, a woman encounters different norms in the lab with her peers, at a social event with professionals, or as a guest speaker (Carlone & Johnson, 2007). Women’s issues in STEM tend to be investigated in broad categories (e.g. “science” or “STEM”), yet every discipline has a distinct culture (Herzig, 2004). The differing nature of knowledge in each discipline carries different social characteristics for its production and involves different questions, methods, and cultures; all of these factors have, in turn, distinct effects on women’s choices to persist in their discipline (Herzig, 2004).

Cultural production—the meanings developed by groups in their everyday activities—suggests that the outcome of situation or a meaning produced a particular setting is never predestined or fixed, but instead is continually in question (Carlone & Johnson, 2007). The reasons why STEM women’s careers are limited and why so few reach the highest levels in academia are culturally broad and not restricted to specific academic communities (Talves, 2015). Social production of STEM occupations, rather than the nature of the scientific process itself may stand in the way of more flexible arrangements for women’s professional development (Subotnik & Arnold, 1995). In Finland, a counterexample, society does not penalize academic STEM women for taking time to raise a family; instead, women are enabled throughout their careers to combine their ethic of care with their need for intellectual challenge (Tirri & Koro-Ljungberg, 2002). Students in STEM believe in the importance of having

a critical mass of women students or women of color students (Herzig, 2004). Strength comes in numbers, and female STEM students may be constructed as “talented” not because of any definable characteristic such as ability, but because they possess particular types of cultural capital that align with academia’s norms and expectations (Herzig, 2004). In most Western societies, however, women are vastly underrepresented in gatekeeping processes. For instance, in Estonia only two of the 66 Academy of Sciences members are female, and women have virtually no influence over entry or access to the sciences, resource allocation, information flow, standards definitions, or the external image of their fields (Talves, 2015). American society in particular holds the collective belief that individuals are responsible for their own career success; those values promote the idea that women, who are scarce at the highest levels of STEM, simply do not want to be leaders (Talves, 2015). On the contrary, academic STEM women want to believe that merit and integrity are recognized and rewarded by authorities without the need for self-advertisement (Talves, 2015).

Rather than allowing the attitudes of others to affect their lives, gifted female scientists take action by influencing others in their fields with their own beliefs and values (Tirri & Koroljungberg, 2002). Stories of successful women of color in STEM demonstrate that space exists for individual agency and cultural production in academia (Carlone & Johnson, 2007). Many STEM-talented women of color find ways to negotiate the challenges of working in STEM, and although not all are happy, they are successful and persist (Carlone & Johnson, 2007). Some women of color pose innovative interpretations of how membership in a stigmatized group helps them succeed; for one such woman, others’ assumption that she would be less academically successful than her White counterparts contributed to her persistence (Carlone &

Johnson, 2007). Furthermore, in an effort to resist and respond productively to racist and sexist stereotypes, Black STEM women work either independently, or if possible with a same-race female counterpart (Charleston et al., 2014). Other women assume passive forms of resistance; gender-determined structural factors are difficult to recognize and often, women appear to passively settle into positions that are created for them in organizations (Talves, 2015).

## Discussion

### Comparison of the Studies

The body of literature examined in the current study was remarkable for its virtual absence of feminist research methods. Feminist research places gender at the center of inquiry and the research process, and research is considered feminist when it is “grounded in the set of theoretical traditions that privilege women’s issues, voices, and lived experiences” (Hesse-Biber, 2014). Feminist methods are crucial when undertaking research where women’s position is of primary interest (Grbich, 2013). Of the 18 studies reviewed, only one study (Charleston et al., 2014) employed explicit feminist research methods; that study employed Black feminist epistemology and critical race feminist theoretical frameworks. Two other studies rested on theoretical frameworks closely compatible with feminist research. First, Talves (2016) framed the inquiry within critical discourse theory and approached the analysis in a multiple-case approach. Critical discourse theory aligns with feminist research in it rests on the notion that discursive practices shape social groupings and culture and have the power to limit knowledge and beliefs (Grbich, 2013). Second, Tirri and Koro-Ljungberg (2002) underpinned their inquiry

with critical incidents. Their multiple-case approach to women's critical incidents highlighted the experiences of women and allowed their voices to be heard.

In all, nine of the reviewed studies used qualitative research methods, two of which articulated conceptual frameworks as a priori bases for approaching the research. Nine studies employed quantitative methods and of those nine, six articulated either theoretical or conceptual frameworks.

### Talent Development

Studying only those women who leave STEM brings a risk of overlooking challenges and obstacles conquered by women who persisted (Etzkowitz, Kemelgor, Neuschatz, & Uzzi, 1992). This study conceptualized STEM talent as a set of developed skills, and focused specifically on women who developed exceptional STEM talent. Talent development models are well suited to the study of marginalized groups because they encourage inclusivity in initial identification and selection; for instance, identification of high potential in talent development approaches is more flexible than in traditional gifted education approaches (Dai & Chen, 2014). As the findings of this study show, reasons for talented women's STEM success are immensely complex and suggest that a comprehensive model is necessary to explain the qualitative data from this study. To formulate a conceptual framework to describe women's STEM talent development, we expanded on two existing talent development models: the differentiated model of giftedness and talent (DMGT; Gagné, 2004), the new model for female talent development (Noble, Subotnik, & Arnold, 1996). Although both models account for the effects of intrapersonal characteristics, relationships, and environmental factors to some degree, both

models disregard several of the catalysts identified by our review. First, both the DMGT and New Module for Female Talent Development fail to consider alternative or non-sequential talent development trajectories characteristic of women with family responsibilities. For instance, academic women's priorities change after they become parents: they may reduce their work hours or take temporary leaves of absence (Ferriman et al., 2009). Further, both models fail to account for the feminine moral and value orientations that affect women's academic and career choices. Both models neglect the effects of interactions between catalysts, and therefore apply poorly to aspects of women's talent development such as STEM identity development. For instance, neither model could be used to explain the "double bind," or the intersection of racism and sexism experienced by women of color in STEM. Finally, the DMGT excludes the effects of perceptions. Perceptions are an important catalyst for women, who are more likely than men to attribute setbacks or lack of progress to themselves rather than outside influences such as discrimination or devoting time to raising children (Talves, 2015).

To address gaps in the existing models, we conceptualized talent development as an ecological system comprised of "a set of nested structures" (p. 3) similar to Bronfenbrenner's ecological systems model (Bronfenbrenner, 1979). The four themes found in our review suggest a four-level system of filters (see Figure 2). Talent development begins with the individual woman and her foundational characteristics such as aptitudes, emotions, interests, values, and perceptions; thus, the first level considers personal attributes that influence how a woman thinks, acts, and feels. The second level focuses on the influence of meaningful interpersonal relationships with family, peers, and mentors; as discussed previously, supportive relationships are important contributors to women's engagement and retention in STEM. The third level

considers the influences in the institutional context; for example, opportunities, barriers, norms and expectations inherent in particular STEM disciplines. The fourth level considers the effects of STEM cultural ideologies such as masculinized gender norms and dominant racial norms.

Development of STEM talent is a dynamic process that does not necessarily proceed sequentially through these four levels; for example, positive social interactions can influence personal characteristics such as perceptions and values, or institutional supports such as professional groups for women can bring about new social relationships with other STEM women.

#### Implications for Research

Many questions remain about how and why some women persist in STEM and develop exceptional talent. Future research must consider that catalysts of women's STEM talent development are multilayered and interrelated. First, an individual woman's talent development trajectory depends on the intersection of her personal foundational characteristics such as sex, age, ethnicity, personal values, and family responsibilities. Currently no research exists on relationships between a woman's age and her talent development (Tate & Linn, 2005). Also notably absent from the literature are the experiences of alternative-gendered women in STEM, including women who identify as transgender, androgynous, or fluid.

Meaningful comparisons could deepen understandings about women's talent development in STEM; for instance, Dabney & Tai (2014) suggest the need for studies that compare STEM women to one another rather than comparing them to men, and George-Jackson (2014)

suggests the need for research that compares STEM women and men within their own ethnic groups.

Second, future research should apply conceptual models that capture not only variation among individual women in STEM, but also the effects of their social experiences and their institutional environments. As Herzig (2004) pointed out, the “pipeline” analogy is a poor conceptual model because it combines all women conceptually in a single group that overlooks inequitable environments and meaningful differences between women in that group.

Conceptual models adapted from models used to understand talent development in the arts could be useful for understanding women’s STEM talent development. For example, evaluation and assessment conducted in studio environments is typically conducted collectively by all participants; such an arrangement could be adapted for use in laboratory environments (Subotnik et al., 2001). Feist (2006) pointed out the overreliance on self-report survey data and suggested applying longitudinal models that emphasize change and growth in STEM interest, motivation and talent growth from childhood through adulthood.

Third, relationships between women’s talent development and their STEM identity are incompletely understood. There is a need for a deeper examination of mechanisms and contexts in which women adopt, reject, or construct STEM identities and practices, and how those actions impact women’s STEM success (Carlone & Johnson, 2007); in particular, more work is needed on STEM identity construction viewed through the lens of societal elements (Tirri & Koro-Ljungberg, 2002). A need also exists for research examining the stability of women’s STEM identities over time; future research could bring insight into whether STEM identity is an achievement or an ongoing, dynamic process (Carlone & Johnson, 2007).

Fourth, several STEM domain-specific topics warrant additional research that disaggregates the different STEM disciplines, especially when investigating STEM participation and persistence (Gavin, 1996). For instance, little is known about interactions between women's communication styles and specific STEM disciplinary communication styles--Herzig (2004) hypothesized that although many women find the assertive communication style typical in most STEM disciplines uncomfortable, talented women may be protected to some degree by their exceptional verbal ability.

Finally is the need to examine women's STEM success from a feminist perspective and thus calls for the application of qualitative research methodologies. Traditional research methods rooted in the postpositive tradition assume an objective, value-free science where researcher is detached from "researched." Qualitative research methodologies and epistemologies challenge those premises by allowing an inquiry focused specifically on women's individual experiences and perspectives (Hesse-Biber, 2014). In terms of feminine perspectives, women in STEM are more interested in how ideas and facts fit together than in examining information out of context (Rosser, 1995). Research on programming and pedagogy in higher education should evaluate the particular ways in which interventions impede or enhance women's participation and persistence (Charleston et al., 2014). In particular, a closer examination of practical and classroom experiences and their impact on women's academic achievement in college STEM are needed (Dabney & Tai, 2014). Principally, research should examine programming interventions that target both women and men; such interventions could have indirect positive effects on women, for instance by increasing their sense of belonging in STEM (Smeding, 2012).



## Implications for Practice

### *Pre-College Contexts*

The findings offer a number of practical strategies for developing girls' STEM talent prior to college. First, women who develop exceptional talent in STEM found their interest (Dabney & Tai, 2014) were recognized for STEM potential and had strong STEM experiences (Carlone & Johnson, 2007; Herzig, 2004) in childhood. Early authentic research experiences and career exploration can help students draw an accurate picture of a discipline's nature and practices and find their interests. Second, women are more likely than men to gravitate towards disciplines where they can express altruistic values (Feist, 2006; Lubinski et al., 2001; Webb et al., 2002). STEM curricula should emphasize how STEM can serve humanity, for example by designing learning around authentic global problems. Third, successful women develop strong STEM identities in their childhoods (Tirri & Koro-Ljungberg, 2002). Schools should help girls envision themselves as scientists, for instance through social supports such as mentoring, opportunities to serve their communities through STEM, and structured STEM research programs. Another strategy for developing STEM self-concept involves exploration and discussion of the lives and careers of elite women scientists, especially those of color. Discussions should include aspects of STEM that women find challenging, such as lack of female role models and masculinized methodologies. Finally, successful STEM women advocate for their interests effectively (Tirri & Koro-Ljungberg, 2002). Schools should discuss gender-based discrimination and concrete ways that girls can speak up about it in a firm and diplomatic manner.

### *College and Graduate School*

Women's STEM identities continue to emerge in early adulthood and stabilize through performance and recognition over time and context (Carlone & Johnson 2007). First, STEM higher education programming should continue to develop women's STEM identities by encouraging women to explore personal "positionality," values, and beliefs in the context of STEM. Second, academic success anchors STEM identity for women of color (Tate & Linn, 2005), making recognition of their potential and achievement crucial to their self-concept as a scientist. College women need social support from female mentors who affirm their STEM aptitudes and are able to share political knowledge and strategies required to excel in academic STEM careers. However, female mentors are in short supply, and thus institutions must reward senior women who dedicate time to mentoring. Institutions must also encourage both male and female faculty to lend attention to female students' capabilities and contributions, and encourage supportive peer collaboration between female students. Third, supportive social environments increase women's perceptions of their future success in a STEM career (Buday et al., 2012). Institutions can foster a sense of belonging by advocating for women and offering student support groups for women in STEM. Leadership must discourage sexist behaviors; for instance by fostering awareness among all faculty and students of the misperceptions and stereotypes associated with STEM women. Favorable classroom environments emphasize the student, connect concepts to the real world, and support conjecture and open discussion of ideas.

### *Post-Graduate Academic and Professional Contexts*

Institutions can incorporate a number of supports that contribute directly to women's persistence in STEM careers. First, many women persist due to the availability of family supports (Herzig, 2004); institutions could accommodate women with families by offering job sharing, extended paid family leave, or by delaying the tenure clock. Second, leaders can use their power to protect women's interests; for instance by recognizing women's talent, and by creating policies that allow women to satisfy both their ethic of care and their need for intellectual pursuits. Leaders should also initiate opportunities for women to lead and take care to ensure gender equity in assignments (Settles et al., 2006). Additionally, increasing diversity among faculty and students can mitigate masculinized work climates that women often find insensitive or isolating (Charleston et al., 2014). Finally, institutions should incorporate an inclusive epistemological perspective sensitive to women's values; for example, ways of working in STEM should accommodate women's communal orientation (Ferriman et al., 2009), their need to perform altruistic work (Carlone & Johnson, 2007), and their need to explore interactions among ideas (Herzig, 2004). Values such as Native American cultural taboos against dissection during pregnancy (Carlone & Johnson, 2007) also underscore a special need for cultural sensitivity and accommodation for women in STEM.

Table 3

*Search Parameters and Initial Results*

Search Terms	Database	Search Limiters	Hits
(women OR female) AND (science OR STEM) AND (gifted OR talent OR success)	Academic Search Complete	Scholarly (Peer Reviewed) Journals Published Date: 1990 - 2016	53
	Education Source	Scholarly (Peer Reviewed) Journals Published Date: 1990 - 2016	65
	ERIC via Ebscohost	Peer Reviewed Date Published: 1990 - 2016	23
	Gender Studies Database	Scholarly (Peer Reviewed) Journals Published Date: 1990 - 2016	28
	Professional Development Collection	Scholarly (Peer Reviewed) Journals Published Date: 1990 - 2016	84
	PsycINFO via Ebscohost	Peer Reviewed Published Data: 1990 – 2016 Population Group: Human	141
	SAGE Journals Online	Disciplines: Education, Family Studies, Gender Studies, Psychology & Counseling, and Science & Society Studies Date Range: 1990 - 2016	22
	<i>Total</i>		<i>416</i>

Table 4

*Screening Criteria*

Criterion	Include	Exclude
Publication year	1990 – 2016	Before 1990.
Publication type	Indexed, scholarly, peer-reviewed journals	Trade journals, magazines, newspapers, predatory journals
Language	English	Other than English
Context	STEM higher education settings in North America and Europe	Contexts other than North America and Europe
Participants	Adult women who have persisted in academic STEM at or above the college level	Studies with participants who failed to persist at or above the college level
Research design	Empirical research (quantitative, qualitative, mixed-methods), meta-analyses, secondary data analyses, and systematic reviews	Non-empirical works (editorials, monographs, non-systematic reviews, and proposals)
Relevance	Purpose aligns with current study's research questions	Purpose fails to align with current study's research questions

Table 5

*Quality Assessment Rubric*

Criterion	4 – Exceeds Standard	3 – Meets Standard	2 – Nearly Meets Standard	1 – Does Not Meet Standard
Purpose	Problem, intent/goal, research questions, and hypotheses. Key terms are identified and operationally defined; ambiguities in definitions are discussed and resolved.	Problem, intent/goal, research questions, and hypotheses. Key terms are identified and operationally defined.	Problem, intent/goal, and research questions are present. Key terms are neither defined nor discussed.	Incomplete; purpose cannot be determined.
Review of Literature	Comprehensively examines state of the topic. Situates the topic within the broader field. Makes compelling connections to past work. Synthesizes and evaluates ideas; offers new perspectives. Inconsistencies, critical issues, and gaps are identified and discussed. Organized by themes or issues.	Comprehensively examines the state of the topic. Makes connections to past work. Synthesizes and evaluates ideas. Inconsistencies, critical issues, and gaps are identified and discussed. Organized by themes or issues.	Examines of the state of the topic. Makes few connections to past work. Lacks synthesis or evaluation. Identifies few important inconsistencies, critical issues, or gaps. Lacks logical organization.	Reports only what has been done. Fails to make connections to past work. Omits important works. Lacks synthesis and evaluation. Lacks logical organization.
Theoretical or Conceptual Frameworks	Frameworks are identified and described in detail. Choices of framework are explained and supported. Alignment of framework with study purpose is discussed and supported.	Frameworks are identified and described in detail. Choices of framework are explained and supported. Alignment of frameworks with study purpose is not discussed but can be inferred.	Frameworks are identified but not described. Alignment of frameworks with study purpose is not discussed and cannot be inferred.	Frameworks are neither identified nor described.
Participants	Describes population, sample and sampling procedures, context, and selection bias.	Describes population, sample and sampling procedures, and selection bias.	Describes population, sample and sampling procedures.	Describes sample but fails to describe population or sampling procedures.

Criterion	4 – Exceeds Standard	3 – Meets Standard	2 – Nearly Meets Standard	1 – Does Not Meet Standard
Methods	Procedures, analysis methods, and instruments and their administration are described in detail sufficient to support replication. Evidence of validity and reliability is provided. Potential bias is discussed. Methodological decisions are supported.	Procedures, analysis methods, and instruments and their administration are described in detail sufficient to support replication. Evidence of validity and reliability is provided. Potential bias is discussed.	Procedures, analysis methods, and instruments are described, but detail is insufficient to support replication. Evidence of validity and reliability is provided.	Procedures, analysis methods, and instruments are described, but detail is insufficient to support replication. Evidence of validity and reliability is not provided.
Results and Conclusions	Data displays synthesize information or visualize procedures. Discussion connects findings to past work. Proposes future directions for research. Conclusions address the problem or questions. Implications and limitations are identified and discussed.	Data displays are present (tables, charts). Discussion connects findings to past work. Proposes future directions for research. Conclusions address problem or questions. Implications and limitations are discussed.	Data displays are present. Discussion fails to connect findings to past work. Conclusions address the problems or questions. Future directions, implications or limitations are missing.	Fails to connect findings to past work. Conclusions fail to address problem or questions.
Significance	Articulates the cross-disciplinary scholarly and practical significance of the study.	Articulates scholarly and practical significance of the study.	Articulates scholarly or practical significance within the field.	Not articulated.

Table 6

*Data Extraction Protocol*

Extract	Description
Purpose	Purpose, objectives, or research questions addressed
Research context	Geographic location and cultural context of research
Research design	Qualitative, quantitative, mixed-methods, systematic review, or meta-analysis
Participants	Demographic characteristics of participants
Frameworks	Description of theoretical or conceptual frameworks, if present
Key findings	Summary of main findings and conclusions



Table 7

*Summary of Extracted Data*

Author/Year	Purpose	Context	Participants	Design	Frameworks	Findings
Buday, Stake, & Peterson (2012)	Examine how science-talented individuals' sources of support and possible selves influence perceptions of a science career and career outcome.	U.S.	81 science-talented young adults (33 women).	Quantitative	Eccles' Expectancy Value Theory; Larose et al.'s Sociomotivational Model of Persistence	Social support contributed directly to women's and men's ability to envision themselves in a future science career. No gender differences were found in predictors of women's and men's perceptions and choice of a science career.
Carlone & Johnson (2007)	Understand how successful women of color negotiate their science experiences, and develop and sustain their science identities.	U.S.	15 science-talented undergraduate women of color.	Qualitative	Science identity conceptual model	Recognition by others is important for women of color in three science identity trajectories: research scientists, altruistic scientist, and disrupted scientist.
Charleston, George, Jackson, Berhanu, & Amechi (2014)	Examine the experiences of Black female computing aspirants at various levels of academic status.	U.S.	15 science-talented Black college women majoring in computer sciences.	Qualitative	Black feminist epistemology; critical race feminist theory	Race and gender are confluent and inseparable in the lives of Black female aspirants in computing; racism and sexism persist in STEM education and computing specifically; and institutional culture is a significant consideration in the study of underrepresented populations.
Dabney & Tai (2014)	Examine differences among women in chemistry and physics based on personal motivations and background factors.	U.S.	1,137 female doctoral students and scientists in chemistry and physics.	Quantitative	None	Females who have higher secondary and postsecondary grades and positive experiences in postsecondary chemistry as well as negative postsecondary physics experiences are more likely to enter the field of chemistry as opposed to physics.
Feist (2006)	Understand why science-talented women and minorities may opt out of careers in the physical sciences.	U.S.	Study 1: 161 Westinghouse finalists (50 women); Study 2: 112 members of the NAS (20 women).	Quantitative	None	A high proportion of female and male participants earned a doctoral degree in science-related fields; women were more likely than men to change to non-scientific fields; age that science talent was recognized was an important predictor of lifetime productivity.

Author/Year	Purpose	Context	Participants	Design	Frameworks	Findings
Ferriman, Lubinski, & Benbow (2009)	Examine whether gender differences in lifestyle preferences contribute to gender differences in occupational achievement among high-potential groups.	U.S.	714 adult (346 women) Cohort 5 SMPY participants.	Quantitative	Gottfredson's theory of circumspection; Hakim's preference theory	Women favored a more communal, holistic perspective emphasizing community and less time devoted to career while men assumed a more career-focused perspective. Male-female representation in high-level, time-intensive careers differed despite similar profiles of abilities, interests, and educational experiences.
Gavin (1996)	Identify major sources of influence that encouraged women to choose mathematics as a college major.	U.S.	16 diverse undergraduate women majoring in math or statistics at a highly selective women's college.	Qualitative	None	Women's development in math hinged on the need for personal and practical relevance. Personal relevance promoted positive self-concept, while practical relevance gave meaning and purpose to the women's endeavors in math.
George-Jackson (2014)	Investigate undergraduate women's persistence in STEM majors.	U.S.	17,005 science-talented college graduates (49.4% female).	Quantitative	None	Being female and majoring in physical science, computing, math, or engineering moderately reduced the odds of persisting in the initial major. Having parents with income less than \$60K substantially reduced the likelihood of persisting in the initial major.
Herzig (2004)	Propose a theoretical framework, based on social and academic integration, for understanding small numbers of women and students of color who persist in doctoral mathematics.	U.S.	11 research studies that reported on the experiences of doctoral students in mathematics, and 13 studies that illuminated aspects of the persistence framework in higher education.	Systematic review (qualitative)	Persistence conceptual framework; communities of practice	The success of women and students of color in doctoral mathematics depends on participation in communities of practice and on the student's successful integration into the community.
Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson	Examine how talented math-science graduate students' talents emerged and developed as a function of psychological attributes and personal experiences.	U.S.	732 math or science-talented graduate students (346 female) and 756 SMPY participants (228 female).	Quantitative	None	Developing exceptional scientific expertise requires special educational experiences, but those necessary experiences are similar for high-ability women and men.

Author/Year	Purpose	Context	Participants	Design	Frameworks	Findings
(2001)						
Settles, Cortina, Malley, & Stewart (2006)	Examine how features of the climate and experiences relate to important job outcomes for women faculty in science.	U.S.	135 female tenure-track faculty members in natural sciences (N=135) and social science (N=73).	Quantitative	None	Women scientists experiencing more sexual harassment and gender discrimination reported poorer job outcomes. Perceptions of a generally positive, nonsexist climate, as well as effective leadership, were positively associated with job outcomes after controlling for harassment and discrimination.
Smeding (2012)	Investigate implicit gender-STEM stereotypes and their relation to performance among female and male engineering students.	France	27 aerospace engineering students (13 female) and 28 high ability humanities undergraduates (14 female).	Quantitative	None	Female engineering students hold weaker implicit gender-STEM stereotypes than other groups of students, and those stereotypes are not necessarily negatively correlated with math performance for all women.
Subotnik & Arnold (1995)	Explore how the pursuit of career and life satisfaction was defined and resolved by elite female scientists during the process of career establishment.	U.S.	11 women from the Westinghouse and Illinois valedictorian studies who completed a terminal degree in science, were employed full time in science, or were committed to high level science careers.	Qualitative	Grounded theory	Factors that influenced aspirations and attainments of women at the threshold of top level careers included professional advancement structure in science, the funding climate for science research, dual career constraints, commitment to social change, and maintenance of friendship and family ties.
Subotnik, Stone, & Steiner (2001)	Identify variables that lead to retention and attrition of talented men and women in science.	U.S.	85 Westinghouse talent search winners (1983 cohort; 33 women).	Qualitative	None	Science-talented individuals distinguished themselves whether or not their parents had achieved high economic status or advanced degrees. Accessibility of a mentor increased one's status and elicited further resources and recognition. Reasons for leaving science included disillusionment with the lifestyle and inadequate emotional or intellectual support from the institution.
Talves (2016)	Understand how self-positioning strategies of females in the natural	Estonia	20 female scientists with master's or	Qualitative	Laclau & Mouffe's discourse theory	Strategies that women use reflect different coping and resilience mechanisms in overcoming academic and career obstacles rooted in gendered processes within organizations.

Author/Year	Purpose	Context	Participants	Design	Frameworks	Findings
	sciences and technology are influenced by discursive processes of career creation, success, and excellence in science.		doctoral degrees in physical sciences.			Gender neutrality, trivializing, and superiority strategies reflect tensions between women's self-positioning and academic excellence, which are framed by gendered symbols of achievements and careers in science.
Tate & Linn (2005)	Characterize the experiences of women of color engineering students and identify issues and concerns those students encounter.	U.S.	5 upper-level undergraduate women of color studying engineering.	Qualitative	Multiple identities conceptual framework	Academic and social peer groups served as important supportive networks for women of color engineering students. A sophisticated intellectual identity began to emerge toward completion of their undergraduate programs. The women possessed strong academic identities but were plagued by feelings of difference and a sense of not belonging.
Tirri & Koro-Ljungberg (2002)	Identify choices and compromises that gifted women make in order to succeed in academia.	Finland	5 female Academy science professors and 6 female mathematics Olympians.	Qualitative	Critical incidents theory	Gifted women in the study made important life choices that promoted their talent and academic career development. Those choices included important decisions involving work, family, beliefs, and values. The majority of the women made compromises related to their scientific interests, as well as personal compromises.
Webb, Lubinski, & Benbow (2002)	Investigate determinants of attrition in math and science among mathematically talented individuals.	U.S.	1,100 SMPY participants (350 women) who anticipated an undergraduate major in math-science.	Quantitative	None	More women than men completed undergraduate degrees outside math-science, but many individuals who initially completed nonmath-nonscience degrees ultimately chose math-science occupations.

Table 8

*Preliminary Categories*

Category	Description
1	Individual or personal characteristics
2	Personal preferences
3	Interest in STEM
4	Attitudes, attributions, motivations, or orientations
5	Background or preparation for academic STEM
6	Ability or aptitude profile
7	Productivity and achievements
8	Choices and strategies
9	Values and beliefs
10	STEM Identity
11	Perceptions
12	Mentoring, academic, and professional supports
13	Peer and family supports
14	Recognition by others
15	Programming or interventions
16	Academic and professional environments or climates
17	Social integration into STEM communities
18	STEM cultural norms and stereotypes
19	STEM cultural production and reproduction
20	Power relations in STEM
21	Controversies or dissonance across the literature

Table 9

*Major Themes across the Selected Literature*

Theme	Summary Description
Talented women who succeed in STEM share similar personal characteristics, values, perceptions, and choices.	Women who develop exceptional talent in STEM are intellectually capable, academically prepared, and have a strong interest in STEM. Their beliefs, values, and care ethic shape their professional goals. Their choices center on maintaining a healthy work-life balance.
Positive social interactions with family, peers, and meaningful others catalyze women's success at high levels of STEM.	Women's success in STEM is catalyzed by social interactions such as mentoring, peer and family emotional support, and recognition of talent by meaningful others.
Supportive institutional characteristics catalyze women's success in STEM.	Although barriers do prevent many women from reaching elite levels of achievement in STEM, institutions can create conditions and opportunities that mitigate barriers. For example, institutions can discourage gender bias or apply interventions that fully integrate women into male-dominated organizations.
Successful women in STEM resist culturally reproduced masculine norms and ideologies in STEM through personal agency and cultural production of their own norms and values.	Dominance is transmitted culturally when people or institutions minimize women's perspectives and values, maintain conditions that preclude life-work balance, or prevent access to gatekeeping roles. Women resist masculine norms by producing their own norms, leveraging their differences, or seeking STEM niches where they feel free to exercise feminine ways of thinking and working.

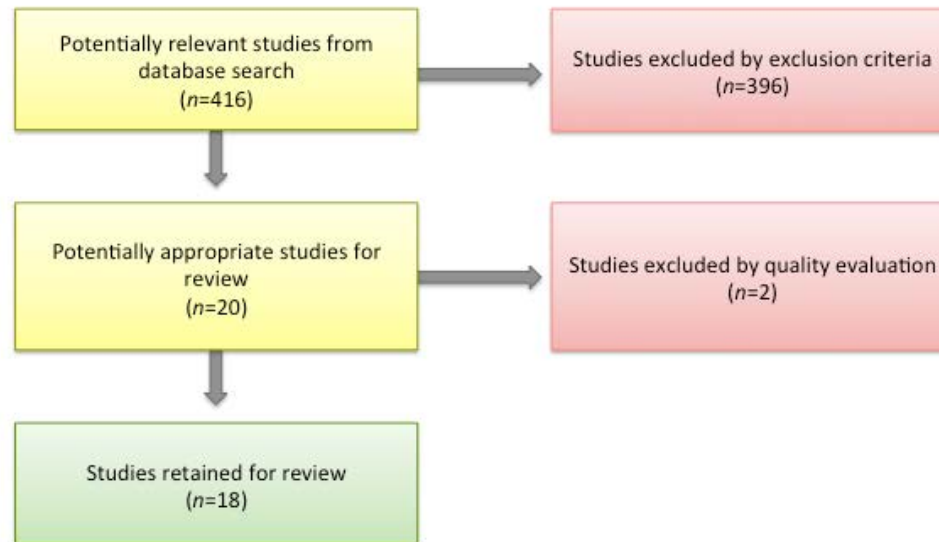


Figure 1. Article selection flow diagram.

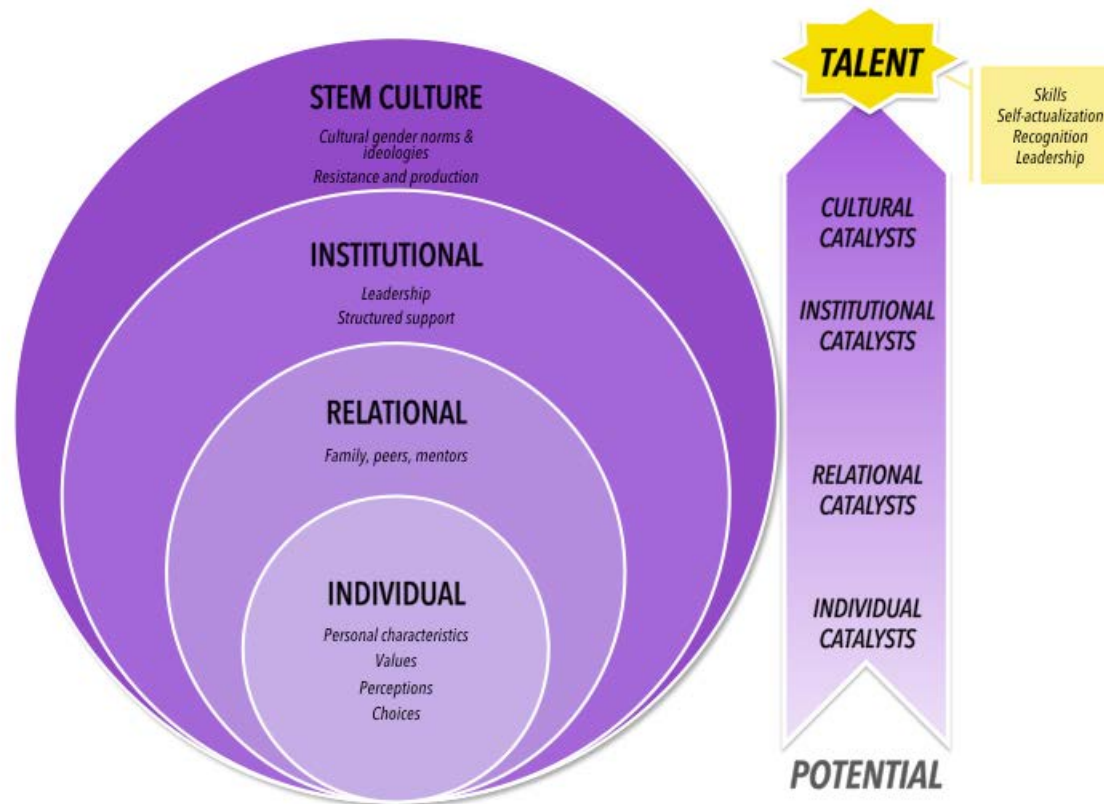


Figure 2. Conceptual model of women's talent development in STEM.



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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?



APPENDIX C  
PRELIMINARY NODES

Preliminary Node	Number of Segments
Creative or innovative thinking style or approach	41
Multiple interests or multipotentiality	31
Early support or encouragement from family or teachers	24
Personal experiences related to gender bias	24
Decision to pursue stem	23
Event or experience that impacted career trajectory	22
Humility	22
Intellectual excitement or deep passion for one's work	22
Interdisciplinary orientation	22
Altruistic or care orientation	20
Drive to explore and discover	20
Dedication to work despite challenges	19
Purposeful or active or self-motivated	19
Support from a mentor or advisor	19
Inclusiveness or receptivity to diversity	18
Low in neuroticism (big 5)	17
Beliefs, philosophies, epistemologies or ideologies	16
Pioneer or first	16
Early educational resources or quality of schooling	15
Challenges existing paradigms (approaches to thinking and working)	14
Parental background in education and or stem	14
Motivated to teach and share knowledge	13
Preference for complex, difficult, big problems	13
Willingness to travel, e.g. internationally, for research	13
Desire to collaborate or share work on difficult problems	12
Peer support or friendship	12
Unconventional	12
Early recognition	11
Nature of problems or questions - e.g. finding connections, integrating things	11
Preference for slow, thoughtful work on a deep problem	11
Resistance to gender norms or conventions	11
Resistance to scientific gender norms	11
Self-confidence or strong stem identity	11
Strategies for managing work life balance	11
Cares for others or helps others	9
Early experiences that had lasting influence	9
Engages in exercise or maintains healthy lifestyle	9
Attitude toward gender discrimination or bias in stem	8
Career decisions impacted by factors outside stem	8
Detour from academic trajectory	8
Early interest in stem	8
Important decisions that determined career path	8
Mentor, advisor, coach for students including women	8
Prestigious awards and recognition	8

Self-advocacy	8
Takes on unusual or challenging tasks or projects outside comfort zone	8
Early role models	7
Institutional culture	7
Motivated by self-actualization and society's enrichment	7
Networking with other stem academics	7
Support from spouse or family for career	7
Supports women in stem	7
Work ethic - belief that hard work is critical to success	7
Adventurous	6
Collegial - shows respect for peers and mentees	6
Early involvement in science research	6
Motivations - integrity or doing the most good	6
Recognition by gatekeepers	6
Institutional support - funding	5
Introversion or extroversion (big 5)	5
Late development of specialization or primary interest	5
Pursues innovative changes in her field	5
Early strength of identity or self-concept	4
Family-work balance decisions and effect on trajectory	4
Influence of important female role model	4
Organized support groups or study groups	4
Pioneering work or recognition	4
While still very young, made major contributions or achievements	4
Desire to find one's own problems or questions	3
Desire to leave a legacy	3
Fast ascent to top of field	3
Important, long, or numerous postdoctoral experiences	3
Institution characteristics (size, location) were important	3
Love of the academic life	3
Makes the most of free time - balances work with fun	3
Plans for contingencies or has an out	3
Seeks opportunities to contribute	3
Topic of wide interest or favorable societal response to discoveries	3
Unstructured approach - trajectory unfolded holistically rather than systematically	3
Broad preparation - provide tools of science (institutional support)	2
Decisions - international opportunity	2
Sees beauty in science or math	2
Politically similar to departmental colleagues	1

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