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Critical feminist analysis of STEM mentoring programs: A meta-synthesis of the existing literature

Makini Beck¹  | Jillian Cadwell²  | Anne Kern³ |
Ke Wu⁴  | Maniphone Dickerson⁵ | Melinda Howard⁶

¹School of Individualized Study, The Department of Sociology and Anthropology, Rochester Institute of Technology, Rochester, New York, USA

²Department of Civil Engineering, Washington State University Tri-Cities, Richland, Washington, USA

³Department of Curriculum and Instruction, University of Idaho-Coeur d'Alene, Coeur d'Alene, Idaho, USA

⁴Department of Mathematical Sciences, University of Montana, Missoula, Montana, USA

⁵Department of Business and Workforce Development Division, Evergreen Valley College, San Jose, California, USA

⁶Department of Biology, Gonzaga University, Spokane, Washington, USA

Correspondence

Makini Beck, School of Individualized Study, The Department of Sociology and Anthropology, Rochester Institute of Technology, Rochester, NY 140623, USA.
Email: mzbind@rit.edu

Abstract

We conducted a meta-synthesis review of existing literature on science, technology, engineering, and math (STEM) mentoring programs for women. Critical feminist theory (CFT) was used to understand how mentoring programs support retention and occupational advancement of women in traditionally male-dominated STEM fields. Four primary strands of CFT were explored: gender, oppression/patriarchy, social institutions, and systemic change. Traditional models of mentoring encompass varied approaches, including institutionally enforced programs, formal and informal programs, paired peer grouping, as well as face-to-face and online forums. However, low levels of retention and self-stated lack of professional satisfaction for women in STEM fields continue to plague those professions. This study reviews the literature on mentoring programs that have been implemented to support women in STEM, thus adding to the epistemology of mentoring women in STEM through feminist discourse.

KEYWORDS

feminist, mentoring, STEM

1 | INTRODUCTION

The historically low number of women in science, technology, engineering, and math (STEM) fields across the globe, have raised concerns about equitable workforce opportunities and developments within these fields (MacLean, 2017; Ramirez & Kwak, 2015; Roberts, 2014; U.S. Department of Commerce, 2017). The exclusion of women in STEM related disciplines in higher education and careers from several ethnic backgrounds leads to untapped and limited opportunities for innovation prospects, global competitiveness, economic development, and job creation (Mullins, 2018). Holman et al. (2018) assert that “despite recent progress, the gender gap appears likely to persist for generations” and “the gender gap will not close without further reforms in education, mentoring, and academic publishing” (p. 1). To address STEM gender disparities, educational and workforce mentoring programs have been implemented over the last several decades to encourage the retention of women in STEM fields (Dennehy & Dasgupta, 2017; Jensen et al., 2017; Rosser, 1993; STEMconnector, 2017). These mentoring initiatives were implemented to help women offset the social and structural challenges associated with navigating through traditional and historically male-dominated fields (Cadwell & Kern, 2019; Cain & Leahey, 2014; Hughes et al., 2017; Williams & Ceci, 2015).

In this paper, we review the existing literature on mentoring programs internationally that target women in STEM disciplines. Our goal was to identify the challenges and barriers women in STEM fields face, and we articulate the mentoring models used to enable women to face these challenges. The research questions that guided this study are:

- (i) What can we learn from a meta-synthetic review of existing mentoring programs in STEM, from a critical feminist perspective?
- (ii) What challenges and barriers for women in STEM fields were reported?
- (iii) How do the existing mentoring models align with the tenets of critical feminist perspective?

We combine the work of Dickerson (2015) and Welch et al. (2012) to create a conceptual framework to analyze these mentoring initiatives. We also use this lens to investigate whether the models disrupt oppressive and hegemonic STEM environments for women, thereby promoting structural and systemic change in their institutions to support equity and inclusion. In this light, four primary strands of critical feminist analysis – (i) gender, (ii) oppression and patriarchy, (iii) social institutions, and (iv) systemic – were used to review mentoring programs in science and engineering, medicine and biosciences, computer science information and technology, and mathematics.

We suggest, as mentoring programs aim to support and increase the number of women in STEM fields, there is a need to understand the various program approaches and frameworks. Thus, our work is timely in that we provide a robust body of empirical research documenting the approaches, methods, and programming efforts used to support women in STEM fields. It is our hope that identification of mentoring programs' best practices will lead to future programs and systemic changes that further close the STEM gender gap in both the U.S. and abroad.

2 | THEORETICAL FRAMEWORK

Our paper is grounded in a critical feminist theory (CFT), which merges critical theory and feminist theory. While feminist theory analyzes gender inequality and patriarchy (Martin, 2003), critical theory allows us to examine gender inequality in STEM by identifying “prevailing structures and practices that create or uphold disadvantage, inequity, or oppression” (Baxter & Braithwaite, 2008, p. 290). CFT was largely developed in the field of psychology as a response to androcentric research that claimed women had underdeveloped morality unfit for the workplace, and that this research perpetuated gender inequalities and exclusion of women from positions of power in society (Wigginton & Lafrance, 2019). CFT is a field of inquiry that promotes systemic change and examines whether or not inequalities or exclusions are the result of existing patriarchal systems, and suggests alternatives for institutions to promote egalitarian opportunities.

To change STEM's ethnocentric and androcentric culture requires a framework that critically analyzes how structural systems of power work and continue to work in the lives of those who are marginalized (Charleston et al., 2014; Nganga & Beck, 2017). Early feminists in science have helped to expose and problematize how the STEM community developed along androcentric assumptions, gendered binaries, and ethnocentric systems of knowledge production, thus excluding and marginalizing the contributions and efforts of women's perspectives and ways of knowing (Harding, 1996). Critical feminist theory places women at the center of research study, exposes sex and gender inequity, and explores the ways power and privilege are granted or denied (Stevens & Martell, 2019). Unlike liberal feminism, critical feminism addresses the historical roots of sexism and theorizes how patriarchy continues to reinvent itself throughout each generation (Bucholtz, 2014). At its core, CFT calls us to continuously reevaluate social structures challenging gender equality and equity, and provides a framework for understanding how power relationships in social structures, like educational institutions, reinforce patriarchy through male supremacy (Andersen & Witham, 2011). While scholars have utilized CFT to understand the experiences of women in STEM, our approach is unique in applying CFT to STEM mentoring frameworks. This lens helps us to understand the goals and models of mentoring programs that are designed to support the retention and occupational advancement of women in STEM fields.

In the sections below, we outline the four primary tenets of CFT, which include the interrelated terms gender, oppression and patriarchy, systemic, and social institutions. We developed these salient themes through a review of the critical feminist literature. We later used these themes as codes for our analysis of mentoring programs. While the salient themes in which we focus are complementary parts of interacting systems (Walby, 1989), we have chosen to keep each concept analytically distinct in order to better understand STEM mentoring programs from a CFT lens. For instance, some programs address gender (i.e., women peer to peer mentors) without addressing the systemic or social structures that call for the need of mentoring programs in the first place. Therefore, our attempt to analytically separate the concepts allows us to see which areas of support are emphasized and/or lacking through the lens of critical feminist theory.

2.1 | Gender

Gender is an integral part of identity and is deeply ingrained in the way society postulates and positions individuals on the male-female (or masculine-feminine) binary (Nentwich & Kelan, 2014; West & Zimmerman, 1987). According to Nentwich and Kelan (2014), it is difficult to restructure or escape gender, for it is a social construct that impacts our social perceptions, values, activities, and even the occupational practices and advancements of individuals. For instance, how we acknowledge gender could be understood within workplace relations. Hall et al. (2007) call us to consider the ways women's work and men's work are socially constructed; they explore how various job occupations are categorized as masculine or feminine. Professions such as waitressing, childcare, or teaching, are often associated with women's work and femininity, while professions such as construction or plumbing, are viewed as men's work and masculine (Hall, 1993). These gendered categories become problematic when women work in masculine or male-dominated fields (or vice versa), because doing so violates normative social expectations of what is considered "masculine" or "feminine" work.

In the case of women in STEM fields, the mismatch between women's gender identity and stereotypes of STEM as masculine work often raises difficulties for women in these fields because they are engaging in tasks that challenge gender boundaries and binaries. As Nentwich and Kelan (2014) write, "it is assumed that a job 'has' a certain gender as do the persons performing it. Here, one 'does' gender when doing the job and the gender of both the individual and the job are constructed while doing the job" (p. 126). Therefore, when considering women in STEM fields, it is unrealistic to ignore gender because of the ways the social construction of gender is deeply embedded in occupational expectations and the work women do in these fields. Thus, seeing gender as a situated social practice is integral to understanding how social structures work, and the ways power systems, hierarchies, and the persistence of inequalities are embed-

ded within them. Therefore, CFT aims to challenge the societal construct of gender where the experiences of men prevail over the experiences of women.

2.2 | Oppression/patriarchy

Patriarchy is a culture firmly situated in hierarchy and the gender binary. It privileges the masculine over the feminine and “elevates some men over other men and all men over women” (Gilligan & Snider, 2018, p. 6). A patriarchal society lends itself to sustaining and maintaining male power (dominant group) and females (oppressed group) with minimal or no power. A patriarchal culture maintains gender stereotypes of women being the weaker group that must be overseen by a dominant gender (men).

Patriarchy and the notion of power comes into clearer focus when understanding interpersonal relationships. Individuals shape and affect power relations just as much as the social institutions they are a part of (Collins & Bilge, 2016). This speaks to the roles we play (and our individual responsibility) in perpetuating social inequities, as well as to the ways we believe and internalize gendered norms about women in STEM. Therefore, patriarchy is not solely about male domination but also about how all people (men and women) internalize, believe in, and perpetuate oppressive ideologies in social relationships.

It is not by chance that fewer women and young girls choose STEM fields. In publicly supported schools from kindergarten (K) through 12th grade (K-12) and up to the professional ranks of the academy and industry, we continue to see the ways power and oppression afford opportunities to some (in this case, boys and men) while denying them to others (girls and women). Patriarchal ideologies shape everyday relationships that affect the administration of rewards, punishments, and promotions. These ideologies not only “shape what we think and do” (Collins & Bilge, 2016, p. 28) but also structures opportunities “that put people's lives on paths that make some options seem viable and others out of reach” (Collins & Bilge, 2016, p. 9). This in turn can impact why fewer women choose to enter into STEM fields. A critical feminist lens allows us to examine how power relationships and conscious and unconscious behaviors perpetuate the unequal status of women in these environments.

2.3 | Social institutions

Patriarchy enacts a system of power and control that is perpetuated within large social institutions and structures. Collins and Bilge (2016) delineates four interconnected yet distinct social institutional domains: cultural, structural, interpersonal, and disciplinary. Walby (1989) furthers these claims and identifies six structures of patriarchy to include male violence against women, patriarchal modes of production, patriarchal relations in sexuality, and patriarchal relations in cultural institutions such as religion, media, education, and the state (i.e., the government). These combined definitions allow us to recognize that patriarchy does not work by itself, but rather through a system of social relations (Walby, 1989). A critical feminist lens calls us to examine how (unequal) power relations operate within social spaces (i.e., supervisor/supervisee in a lab setting or instructor/student in a course).

Looking at power in this way allows us to highlight dimensions of hegemony and “reveal how oppression is constructed and maintained” (Carastathis, 2014, p. 307) in each level within organizations. When considering the experiences of women in STEM fields, an analysis of social institutions allows us to see how oppressive power dynamics work to impact women in education and the workplace. In our review of the literature below, we share the ways social institutions like schools and colleges have worked to address inequalities by initiating mentoring programs that seek to change the culture by increasing the numbers of women in STEM fields.

2.3.1 | Systemic

A systemic lens examines intersecting structures that work simultaneously to oppress individuals. It involves understanding that oppression or inequality occurs by not just one factor (i.e., gender) but through an intersection of various factors, such as gender, race, sexuality, nationality, religion, age, and so on (Agosto et al., 2016). In this vein, a systemic analysis acknowledges that women's experiences are not universal (Charleston et al., 2014), but vary in relation to their "social class, power, ethnicity, [and] sexuality within local cultures at particular historical moments" in the world (Qin, 2004, p. 298). For instance, international women who are perceived as an "alien" or "immigrant" may hesitate to speak up for themselves in hostile work situations when compared to women who are a part of the dominant racial/ethnic or nationality group. Thus, CRT helps us understand complex power structures, and the ways women who are a part of the dominant group might use their racial privilege to maintain patriarchal power structures from which they benefit. Therefore, a CFT lens recognizes women's collective experiences as well as their unique intersectional identities.

A systemic approach also calls us to challenge the male-female binary and highlight the experiences of individuals who do not identify within the dichotomy of biologically determined sex (i.e., sex assigned at birth) and gender (culturally attributed roles assigned to sex). For example, the experience of LGBTQ+ individuals in STEM is understudied and few mentoring programs focus on their experiences (Freeman, 2020; Hughes, 2018). Stout and Wright (2016) notes that LGBTQ+ students report increased rates of marginalization and low sense of belonging in STEM more than individuals who identify as women, historically underrepresented minorities, and heteronormative individuals. Therefore, the dominant agentic attributes perpetuated in male-dominated STEM fields can negatively affect the participation of nonbinary individuals in STEM.

Systemic approaches recognize the sociopolitical marginalization of intersectionality and challenge the discursive norms that bind individuals into socially set categories. STEM mentoring programs that seek to disrupt power and the marginalization of nondominant groups examine the culture and structure of the organization and analyze how institutional policies, practices, and strategic plans impact individuals' work. For instance, a systemic approach would analyze tenure and promotion guidelines, the rate at which women move into leadership positions, and unaccommodating family leave policies. These kinds of academic and workplace systems can impact how women feel, progress, and succeed along their individualized STEM pathways. As such, the goal of systemic inquiry is to expose inequity and "call for larger structural social change" within the institution for all constituents (Stevens & Martell, 2019, p. 2; Meyerson & Kolb, 2000).

3 | METHODOLOGY

We are a multicultural team of educational researchers with an interest in STEM fields and social justice. Our positionality as diverse women – a refugee from South Asia, an immigrant from China, two first generation immigrants, one from Jamaica and one from China, and two European descendants – informs our experiences and advocacy on this topic. Our personal experiences as STEM professionals, researchers, and social justice advocates informs our critical lens and drives the impetus for our continued work in this area.

To answer the research questions, we implemented a meta-synthesis method (Cooper, 2015; Higgins, 2016) to conduct a systematic review of the research literature and interpret/synthesize the results through a critical feminist lens.

3.1 | Data collection

Six researchers participated in various stages of the data collection. The first round of review of existing literature included STEM literature published during the years 2010–2018. This time frame provided a boundary for the most current literature cited exclusively on mentoring programs for women in STEM fields. We also included older publications that were closely related within the mentoring scholarship, such as Mayer et al. (2008) and Sambunjak et al. (2006). We used educationally focused databases such ERIC and JSTOR as well as Google Scholar. The key search terms included “mentor or mentoring,” “women,” “STEM” (or one of the STEM disciplines), and “post-secondary support.” A total of 2019 peer-reviewed journal articles, book chapters, and national reports published in English were tagged. Of these entries, we first reviewed the abstract and keywords associated with the electronic search. Sixty-seven article abstracts were found to specifically mention mentor or mentoring women in STEM fields (professional or K-12 and postsecondary education). The full text of each of the 67 articles was read to determine fit in addressing the research questions – challenges and barriers in mentoring women in STEM and/or presentation of a specific mentoring program. Ultimately, 46 articles relevant to the research questions were included for synthesis analysis of this study (Appendix A contains information on the 46 articles).

3.2 | Data analysis

Initially, the analysis included assigning papers according to the STEM focus to researchers with that expertise. Each researcher contributed to an Excel matrix where they sorted and summarized each article into the following categories: article title, authors, the article's reference, abstract, methods, participants, challenges/barriers, mentoring programs to support women in STEM, theoretical approach used in the mentoring program, and the place (e.g., nation) where the study was conducted.

Discussion about the meaning and criteria for critical feminism was centered around the dissertation of one of the research team members (Dickerson, 2015). After discussion and scrutinization, the research team decided on four key themes: gender, oppression/patriarchy, social institutions, and systemic. The themes and association codes were developed and placed in a codebook (see Appendix B).

From the matrix, a Word document with two columns cataloging the observed barriers/challenges and the components of the mentoring program design for each article reviewed was created. We then went through several rounds of individual and group analysis of each article for codes and themes based on our four critical feminist themes (i.e., gender, oppression/patriarchy, social institutions, and systemic). Ultimately, a collated document of all researchers' code-themed findings for each article was reviewed and synthesized. It was decided when three or more researchers identified a theme in a particular article, the theme was attributed to the article. Many articles were assigned more than one theme (see Appendix A). From this synthesized table, descriptive statistics were developed to determine the number of occurrences for each theme in each article and STEM discipline. A Fleiss's kappa (Fleiss et al., 1979, 2013) was determined for the reliability of the six researchers' agreement for the themes assigned to each article. Details on Fleiss's kappa are in Appendix C.

4 | RESULTS

We present the findings using a mixed-methods approach drawing on quantitative and qualitative components to provide a cohesive picture of the findings. The findings are organized into two subsections – quantitative findings and qualitative findings. The quantitative findings give the overall scope of the articles and distribution of patterns (e.g., a summary of the geographic locations on the research conducted in the reviewed articles; and frequency comparison of CFT themes across STEM disciplines of mentoring programs). The qualitative findings provide depth and detail of

the challenges and mentoring programs organized by the tenet of a critical feminist framework: (a) the social construct of gender, (b) how oppression and patriarchy are manifested as a hostile work and classroom environments, (c) the ways gender bias is ingrained in social institutions, and (d) how systemic level concerns contribute to the low retention numbers of women in STEM.

4.1 | Quantitative findings

Of the 46 articles, 12 (26%) were globally based programs, five of which were single-country programs outside of the U.S., and seven were multi-country programs; the majority 34 (74%) of programs reviewed were situated in the U.S. Among the 46 manuscripts, 26 addressed challenges and barriers, while 28 of the articles described models to address women pursuing or persisting in STEM fields. This means that not all articles addressed challenges and barriers, not all articles provided mentoring models and programs, and some articles addressed both. Figure 1 demonstrates the frequency of the 26 articles citing challenges and barriers in the four CFT themes across disciplines – STEM, science, technology, engineering, and mathematics. For example, three articles cited challenges and barriers in the engineering discipline, among which only the CFT themes of gender (two articles) and social institutions (one article) were identified.

Of the 46 articles, 28 articles cited specific models mentoring women in STEM disciplines and fields. Of the mentoring models analyzed, the majority were formal programs (86%) with mentees and mentors being matched for at least 1 year. A smaller percentage (14%) of the models involved informal mentorship activities (e.g., networking events and panelist presentations) bringing mentees and mentors together for an indeterminate amount of time. Among the models, mentees and mentors engaged in face-to-face meetings in approximately 95% of the models, while some models had an online component, making them hybrid models. Furthermore, about 43% were peer-to-peer among the participants, while 52% were peer-to-peer along with faculty mentors. Sixteen percent of mentee target participants were K-12 students, 37% were undergraduate and/or graduate students, 37% were faculty, and 10% were professionals in the field. The remaining models comprised a spectrum of education/career levels. Four of the 28 articles cited that mentoring models had a theoretical perspective that guided the specific mentoring program (see Appendix A): community of practice, living learning community, nested mentoring approach, and relationship cultural theory and narrative practice.

The mentoring models were coded according to the themes: gender, oppression/patriarchy, social institutions, and systemic. Figure 2 indicates the number of articles reviewed and focused on or demonstrated a particular critical feminist characteristic in the mentoring program. Of the 28 articles reviewed, nine articles cited mentoring programs in the general STEM discipline, among which only three CFT themes of gender (three articles), oppression/patriarchy (five articles), and social institutions (one article) were identified.

Next, we address each of the four CFT framework themes (see Appendix B) with the goal of identifying how challenges and barriers women in STEM fields experience (Research Question 1) are addressed by targeted models (Research Question 2).

Figure 3 provides a comparison of the themes for the articles identified the challenges and barriers versus those identified mentoring models directly addressed those challenges and barriers. From this analysis, we found the mentoring models identified in the literature were inconsistent with the barriers and challenges faced by women in STEM fields. From Figure 3, it appears many of the models addressed the social institutional level models; however, the social institutions represented a spectrum of mentoring programs: ad hoc, U.S. National Science Foundation, peer mentoring, and other funded programs. Below, we discuss the nuances and limitations of these institutional mentoring models.

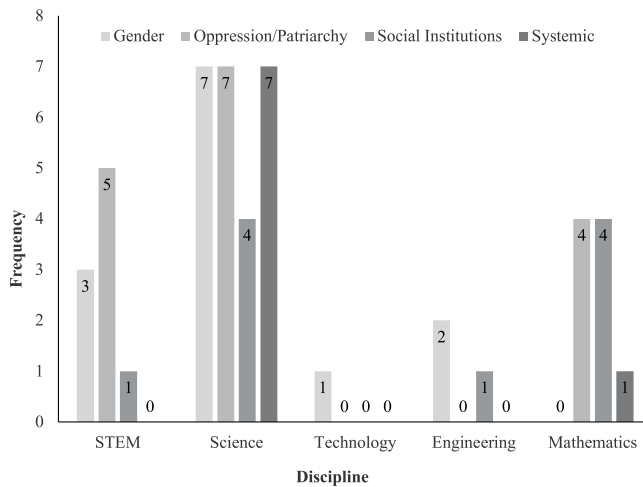


FIGURE 1 Cross-disciplinary comparison of critical feminist theory themes relating to challenges and barriers

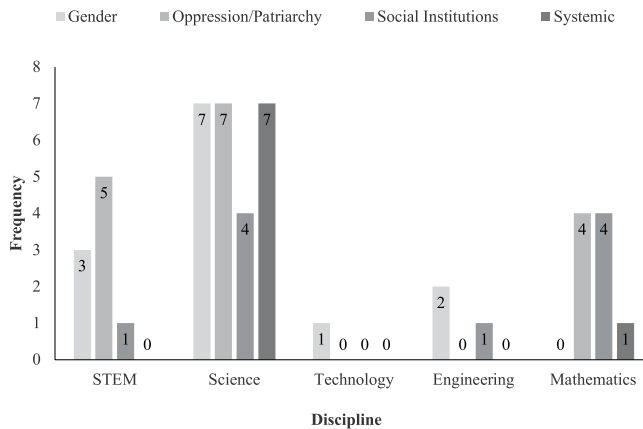


FIGURE 2 Cross-disciplinary comparison of critical feminist theory themes addressed by mentoring models

4.2 | Qualitative findings

In this section, we qualitatively review the models used to mentor women in STEM fields. We used the four themes of a critical feminist framework – gender, oppression/patriarchy, social institutions, and systemic – to analyze the mentoring models found in the literature. For each theme, we address the challenges and barriers women face, as well as the mentoring models we found addressing those challenges.

4.2.1 | Theme 1: Gender

Of the articles reviewed, 50% of the 26 articles that identified challenges and barriers cited “gender” as an obstacle for women and girls in STEM fields (see Figure 1). Inequitable gender biases ingrained in the U.S. culture impact girls while in grade school and have lasting (psychological) effects up through college and into their chosen professional field. Brickhouse et al. (2000), for instance, noted that girls tended to lose interest and become alienated in science by seventh and eighth grades. Also, during science lessons they noticed that boys became more didactic and assertive

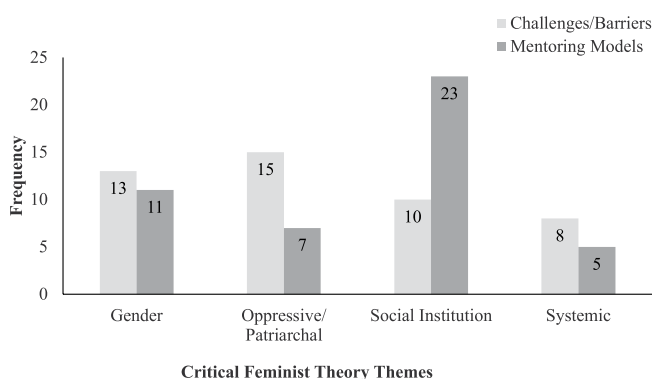


FIGURE 3 Frequency of identified challenges and barriers versus mentoring models aimed at addressing them

answering science questions, thus impacting girls' participation and encouragement in the topic beyond high school. These observations are not meant to assert that boys are the reason girls appear to be disinterested in STEM, but rather to call attention to the structure and culture of K-12 classrooms as having an impact on girls' interest in the field. For these reasons, 11% of mentoring programming initiatives we reviewed targeted young girls (Cole, 2014; Guise et al., 2017; Stoeger et al., 2017).

Reid et al. (2017) suggests how society plays a role in reinforcing implicit gender bias. They draw on Hill et al. (2010) that note:

Although the aim of increasing participation of women in STEM is important, it is not easily achieved. Societal beliefs, expectations and gender bias have a negative impact on participation of women in STEM. Implicit bias is common, even among individuals who reject gender stereotypes. People are more likely to associate STEM with men than with women. Negative stereotypes lower women's test performances and aspirations for careers in STEM (p. 19).

As they note, gender bias is influenced by negative stereotypes situated in incongruent expected roles of who should be a scientist or mathematician (Aikens et al., 2017). These stereotypes can also be seen in college settings where student evaluations have shown significant overall bias for male STEM faculty over women professors (Arnett, 2015; Graves et al., 2017). Gender bias can also be seen in who gets selected for STEM positions as well as how women and men are evaluated for competency (Arnett, 2015). Even when women have identical qualifications (and in some cases have achieved advanced degrees at higher rates than men), men are often selected for positions (Arnett, 2015) and occupy a larger percentage of jobs at the higher management and administration levels (Block & Tiejien-Smith, 2016).

Mentoring models seeking to address gender bias sought to promote psychosocial and emotional support for women and girls. Stout et al. (2011) provide a typical mentoring program found in the literature. Their goal was to help change the way women view themselves in STEM fields by focusing on undergraduate women. Their program tested a stereotype inoculation model exploring same-sex mentors who were peers, faculty, and professionals in STEM fields. In a longitudinal study and from a series of three studies, they found women role models improved women mentees' self-concepts even when negative group stereotypes were addressed. They also found "the more women identified with same-sex experts the more they reported wanting to pursue STEM careers" (p. 262).

Many of the same-sex mentoring models addressed cultural stereotypical gender perceptions either through formal (Van Oosten et al., 2017) and informal (Welch et al., 2012) mentoring approaches. Across the board, their program goals were developed to help women overcome gender bias by instilling positive self-concepts thereby improving "women's self-concept..., attitudes toward STEM, and motivation to pursue STEM careers" (Stout et al., 2011, p. 255).

4.2.2 | Theme 2: Oppression/patriarchy

Of the articles reviewed, 58% percent of the 26 papers that addressed challenges cited oppression or patriarchy as a major barrier for women in STEM fields (see Figure 1). Patriarchy often fosters hostile work environments for women in predominantly male departments or institutions (Pechtelidis et al., 2015). Low representation of women in the field frequently causes them to feel isolated or invisible, and their work contributions are seen as insignificant (Borum & Walker, 2012; Herzig, 2010; Pechtelidis et al., 2015). According to Clancy et al. (2017), women of color reported feeling unsafe in the workplace due to gender, and 28% reported feeling unsafe due to their race. Many of the women in the sample found themselves skipping out-of-work or professional events because of the hostile culture of their departments (Clancy et al., 2017). Dennehy and Dasgupta (2017) describe what hostile work environments look like in the field of engineering:

Many engineering environments are subtly unfriendly or sometimes overtly hostile for women. The numeric scarcity of women, nonverbal behavior from male colleagues that excludes women from professional conversations, use of masculine pronouns to refer to all scientists and engineers, and the prevalence of sexist jokes all signal to women that they are outsiders who do not belong in engineering (p. 5964).

Similarly, Herzig (2010) describes hostile and patriarchal environments in mathematics:

In mathematics in particular, women have reported blatantly sexist behavior, including unwanted sexual advances from faculty, tolerance of public sexist comments, and professors who openly state that women are not as smart, dedicated, or talented as men (p. 5).

Moreno et al. (2014) similarly indicated women in their study attributed patriarchy and stereotype of gender roles as one of the main obstacles in their progression to succeed in computer science technology. The women cited chauvinistic attitudes from teachers, other students, and employers as reasons women choose to isolate themselves in their place of work. The women in their study also reported feeling uncomfortable in social gatherings due to socially exclusive conversation topics or activities not appealing to them, thus causing further isolation at these events.

Mentoring models addressing hostile patriarchal structures overtly addressed power structures in the institution. These models also sought to advance women to leadership positions to help rebalance the power structure at the top of the organization. The Leadership Lab provided an exemplary formal face-to-face mentoring approach to address the redistribution of leadership by women in STEM fields (Van Oosten et al., 2017). Participants engaged in experiential learning modules over three months and were mentored by women instructors to help participants “explore their passion, values, career aspirations, emotional triggers, and developmental focus” (p. 4). The program also sought to help women understand the barriers often associated with male-dominated workplaces and provided strategies and skills sets to help them “flourish professionally and personally” (p. 3). The program incorporated 360-degree feedback, coaching, and a course curriculum aimed to help women navigate, succeed, and ultimately incite change in “male-dominated and technology-driven organizations” (p. 1). The effectiveness of the program was noted by one participant, an aerospace research engineer, who stated,

The program was an eye opener for me because I felt as if a veil was lifted and I finally saw how under-represented women are in my organization.... We have 30 project managers and only one woman – me.... In meetings, men would take the seats at the table and women would sit behind them.... so at the next meeting, I started sitting at the table. The program gave me courage and tools to manage those difficult situations (p. 4).

The Leadership Lab is highlighted because it simultaneously addressed oppression and patriarchy within a social institution. Exemplary programs such as these aim to help participants navigate hostile work and learning environments, pursue leadership positions, and allow women to feel encouraged and supported by other women in the field.

4.2.3 | Theme 3: Social institutions

Of the articles we reviewed, 49% identified challenges within the institution as forming barriers for women pursuing and persisting in STEM careers. Institutional obstacles such as lack of career guidance, institutional support, and acknowledgment of success were most commonly identified. Varkey et al. (2012) indicate the institutional challenges for women faculty:

Women faculty's failure to make substantial gains in academic rank and leadership is even more alarming given the attention and efforts to correct this imbalance for over 20 years. Lack of mentoring, demands of clinical practice, and family obligations, as well as poor or absent succession planning, have been identified as possible contributors to these disparities (p. 3).

Other challenges, including biased institutional support for women in STEM careers and professions, result in the lower salaries, smaller lab spaces, and fewer substantive mentors and administrative support for women than are available for their male counterparts (Lodish, 2015; Robbins & Fikes, 2017). Furthermore, some articles cited the lower number of women researchers and authors of journal articles and books in STEM fields. Holman et al. (2018) state,

Despite recent progress, the gender gap appears likely to persist for generations, particularly in surgery, computer science, physics, and maths. The gap is especially large in authorship positions associated with seniority, and prestigious journals have fewer women authors. Additionally, we estimate that men are invited by journals to submit papers at approximately double the rate of women (pp. 1–2).

To promote collaboration and participation in scholarly activities, program developers have designed mentoring programs to foster institutional mechanisms supporting professional networking, goal setting, and tools for work-life balance.

The institution-level mentoring models we reviewed sought to retain women and girls and provided pathways for advancement to promotion and leadership in the field. Exemplary mentoring models also encouraged networking, provided career advice, and offered professional development through online and face-to-face mentoring courses. One such model was created at the University of Michigan to target first-generation, underrepresented minority women undergraduate and graduate students interested in all STEM fields (Maltby et al., 2016). Through a living-learning community (LLC) mentoring model, students lived together in a designated residence hall and were matched according to similar academic and career goals. Program advisors enrolled LLC students in the same STEM classes to create a “critical mass” of women and to combat feelings of isolation – they believed placing women together helped to reduce stereotype threat. Participating students reported gains in learning outcomes and achieved higher GPAs than those students who lived in university housing but did not participate in an LLC.

Another exemplary mentoring program, created for women residents and faculty in the field of emergency medicine (Welch et al., 2012), adopted a multidimensional mentoring program to support women physicians at various stages of their careers. The model included virtual mentoring, peer mentoring, and senior mentors who were practicing physicians and faculty. As a result of the program, participants received promotions and more women were nominated for departmental, institutional, and national awards. In addition, a benchmark paid-family-leave policy was created for faculty physicians, and dedicated lactation spaces in the institution were established.

These exemplary institutional mentoring programs initiated strategies to support women while promoting an institutional culture supporting women's work and accomplishments in the field. Our critical feminist framework provided us with the lens to examine the kinds of empowerment strategies and activities used to help women navigate and succeed within their institutions.

4.2.4 | Theme 4: Systemic

As indicated by the articles reviewed, women in general often must adapt to the organizational structure and culture of male-dominated STEM disciplines. Much of the bias among women and men is due to STEM disciplines being initially developed and managed under patriarchal cultural attributes. This point is articulated by Arnett (2015), who stated, "Women have been expected to adapt to the organizational structure and culture of medicine and science built largely by and for men" (p. S64). In STEM fields, women have lagged behind their male counterparts in the acknowledgment of their contributions and achievements when compared to men. Take for example the 1962 Nobel Prize for Medicine/Physiology awarded to James Watson, Francis Crick, and Maurice Wilkins for their discovery of the "alpha helix," the molecular structure of the nucleic acids instrumental to understanding the information transfer of life. However, it was eventually revealed a woman, Rosalind Franklin, an X-ray crystallographer and fellow scientist, was the first to observe and articulate the structure of the DNA double helix (Sayre, 2000).

Mentoring programs addressing systemic concerns in their institutions recognized women experience systemic challenges related to policies and to the intersection of gender oppression and patriarchy (Welch et al., 2012). Of the 28 models analyzed, two addressed systemic changes in an institution or organization. One exemplary program in South Dakota, the Cultural & Attitude program, employed a formal, multitiered, multiyear approach targeting the retention of low-income women pursuing undergraduate engineering degrees (Jensen et al., 2017). The program provided participants with multiple levels of mentors, including peers, faculty, and field professionals, as well as financial aid and scholarships. This organization-backed strategy sought to change institutional culture by helping to build participants' confidence through social activities and technical support in lab exercises, along with multitiered mentorship. As a result, the program had a 2%–10% increase of graduates (depending on major). This is an exemplary program because it systematically provided mentorship, social interactions, and academic support and funding, ultimately retaining women engineering students at their institution.

A second exemplary model, conducted by Whitehead Institute for Biomedical Research, initiated a mentoring program for graduate students and postdocs (Lodish, 2015). Their multiple-mentor model includes peer-to-peer mentors and a lead faculty mentor who also served as the research lab director. The program focused on retaining women in science by creating a supportive environment, promoting "growth and success of those with families" (p. 111). The institution housed childcare facilities and lactation rooms for nursing mothers. Their model made changes to the existing structure of the institution by addressing the challenges of family life hindering the retention of women in science.

Systemic inequity is a principal barrier to women's participation in STEM environments. Pfund et al. (2016) point to some specific systemic challenges and barriers for developing STEM researchers, indicating "inadequate mentoring, lack of understanding about institutional requirements, lack of institutional support, and social, cultural, and environmental factors all posed obstacles to [their] success" (p. S239). For these reasons, systemic barriers contribute to a myriad of concerns embedded within the workplace. From individual sexist and racist encounters to the lack of institutional support and equitable family policies, systemic initiatives utilize a critical feminist lens and takes a proactive stance to address inequities by promoting inclusion and broadening the participation of those who have been marginalized.

5 | DISCUSSION

Our meta-synthesis speaks to the continued challenge of recruiting and retaining women in STEM fields. In her book, *Broad Influence*, Newton-Small (2016) notes, “Perhaps the biggest challenge is getting and keeping girls interested in STEM, from grade school through grad school. By the eighth grade, half of girls are already turned off these subjects” (p. 100). These trends continue into adulthood as women are less likely to hold degrees in engineering, computing, and physical sciences. Moreover, as noted by Dennehy and Dasgupta (2017), “the proportion of women with physical sciences, engineering, and computer science [degrees] is very small relative to men and gets smaller still with every level of advancement” (p. 5964). For those women who persist beyond college and enter into a STEM field, many experience burnout, isolation, and hostile work climates, often resulting in women leaving the field at a much higher rate than men (Arnett, 2015; Dennehy & Dasgupta, 2017; Maltby et al., 2016).

In our review of the literature, we found women's experiences in STEM fields are enhanced when they have strong mentors and facilitators to support their work (Jensen et al., 2017; STEMconnector, 2017). The evidence is clear that traditional models of mentoring, such as institutionally enforced mentoring programs, are less successful for women as measured by retention, professional success, and self-stated professional satisfaction (Diekmann et al., 2010). Instead, models designed to specificity and intentionality match mentors with students and women in the profession were found to be effective in supporting their engagement and achievement (Cadwell & Kern, 2019). In addition, mentoring models using a variety of approaches – such as symposia featuring strong women role models in the STEM workforce, graduate/undergraduate mentoring, online forums, peer mentoring of cohorts with similar career goals, and peer mentoring including senior faculty facilitators – provide a larger spectrum and network for supporting women in the field (Chesler & Chesler, 2002).

Although much of the literature points to mentoring as a successful means to support the recruitment and retention of women in STEM fields, many of the models we reviewed were limited in their approach and scope from a critical feminist perspective. For instance, all of the mentoring models were firmly situated in the gender binary. The spectrum of support for individuals who do not fit into specific gender “boxes” continues to be under-recognized and further marginalized individuals in STEM fields. Individuals belonging to sexual and gender minorities are often asked to reveal themselves to others in their daily lives, even when they are uncomfortable doing so. This can further lead to isolation, difficulties maintaining close relationships, and social avoidance. An exemplary mentoring program should acknowledge these challenges for openly LGBTQ+ STEM students and professionals and should work to support individuals' sense of belonging in STEM fields. Thus, a critical feminist lens allows us to recognize and appreciate “alternative realities and demands of a highly diverse, fluid, and global world” (Gringeri & Roche, 2010, p. 25).

Moreover, few mentoring models addressed intersecting oppressions women face (Bottoms et al., 2013; Maltby et al., 2016). Gender rarely is a factor (or oppressor) by itself (Collins & Bilge, 2016). It usually intersects with other factors oppressing women at all stages and levels, including race, class, gender, age, disability, and sexual preference (Crenshaw, 1991). The mentoring model used at the University of Michigan came closest to addressing intersectionality, as program developers sought to support first-generation, underrepresented minority women graduate and undergraduate students interested in all STEM fields. However, the majority of the models we reviewed did not overtly address intersectionality or the ways mentors or institutions can help alleviate challenges associated with intersectional oppressions. Thus, mentoring programs that involve inclusivity also recognizes the ways systemic barriers work in complex ways to create and reinvent systemic barriers for women, including marginalized people.

Only 7 (24%) of the 28 reviewed articles that addressed mentoring models identified patriarchal oppression and power dynamics perpetuated by both men and women (see Figure 2). Models that tackled issues of oppression involved mentor-mentee discussions around unequal status and lower wages for women, hostility from peers or colleagues in leadership roles, slower achievement rates (e.g., number of published articles and rate of promotion), and preconceived biases (e.g., women are weaker than men, more nurturing than men, or need overseeing by men). The models we reviewed also sought to help women overcome barriers and challenges by addressing feelings of belongingness, isolation, and work-life imbalance and by inviting women mentors to work with women mentees (Van Oosten

et al., 2017). However, few addressed the unspoken reality of oppression and patriarchy perpetuated by colleagues (men and women) who are adult bullies. Such conscious or unconscious behaviors preserve inequitable power dynamics, where eventually the oppressed, instead of striving for justice, may become the oppressors (Freire, 1970). Mentoring initiatives circumvented these concerns by developing programs to help mentees navigate hostile work environments rather than by addressing aggressive individuals who negatively impact a collegial climate within the institution. In these instances, the underlying premise for mentoring programs is to change the individual (who may fall victim to abuse and consequently leave the field) rather than address the structures that allow patriarchy to persist.

Finally, of the programs reviewed, many utilized gender matching approaches (women mentees with women mentors). However, this approach can be limiting as mentees who persist in STEM fields rely on a variety of mentors at varying stages. For example, mentees with both men and women mentors on similar career paths respond well to having access to mentors while engaging in professional development activities and social networking opportunities. Exemplary models also brought mentees together with a spectrum of mentors (some in leadership positions) for varying durations to meet the changing needs of mentees throughout their journeys (Dennehy & Dasgupta, 2017; Jensen et al., 2017). This varied-mentor approach aligns well with the notion of “STEM pathways” which require resilience and adaptability, thereby boosting mentee attainment of their career goals, limiting feelings of isolation, and accessing tools for work-life balance.

6 | IMPLICATIONS

The programmatic interventions reviewed in this paper all share similar goals to recruit, retain, and promote women in STEM fields. This research has implications for stakeholders, such as educators, administrators and leaders, program developers, and researchers. A critical feminist lens provides a framework to facilitate mentoring women in STEM disciplines, fields, and professions which as systematic, sustained, and equitable.

6.1 | For educators, K-12 and postsecondary

As role models, teachers' implicit or explicit perspectives can have an early impact on a student's understanding of and decisions about engaging students in STEM fields. For this reason, teachers should take part in professional development opportunities that enable them to identify implicit biases and inherent classroom practices which negatively impact girls' critical engagement in STEM.

When making decisions on curriculum (e.g., textbooks), pedagogy, and instruction, these educators should be cognizant of noncanonical texts reflecting diversity and inclusivity. Organizations and websites such as tolerance.org, rethinkingschools.org, and resilienteducator.com all provide resources, tools, and articles that help educators examine their classroom practices from critically diverse perspectives. Thus, in order for educators to mitigate the hegemonic practices infiltrating educational systems, they must reflect on following and implementing standard instructional practices and consider the use of critical texts.

Additionally, educators should feel empowered to challenge the status quo at their institutions and question the systemic practices perpetuating a traditional view of who can pursue STEM careers. Educators can lobby administrators and policy makers to support initiatives encouraging representation in STEM fields. Initiatives to recruit, motivate, and support women and other underrepresented individuals would enable a more representative, diverse, and perhaps innovative workforce.

6.2 | For administration, leadership, and program developers

In general, programs and organizations that depend on a human workforce develop programs to entice and recruit individuals into their organizations. Most institutions and entities, public or private, have training and mentoring programs designed to support faculty and staff. However, most programs are developed and delivered to a general and broad audience.

Program developers creating new mentoring programs should reflect on best mentoring practices aligned with the needs of participants. Before designing a mentoring program, developers should conduct a thorough needs assessment on participants' professional goals, expectations, and challenges experienced in the institution. This assessment can inform the goals and structure of the program identified as valuable by participants.

It is crucial administrators, directors, and policy makers conduct a systematic evaluation of their existing programs and identify areas and opportunities to broaden participation, thus advancing diversity and inclusion. Once those opportunities are determined, a systematic analysis of what aspects of "diversity and inclusion" should be mandated as institutional initiatives. The voices and perspectives of individuals from underrepresented and marginalized constituents within the organization must be included.

Typically, researchers study the efficacy of mentoring or training programs. However, much of this research is short lived and focuses on the process and progress of the immediate program. Researchers should plan research studies investigating the sustained and longitudinal impact of these programs.

6.3 | At the systemic level

Dashper (2018) notes that "mentoring and other career development initiatives have an important role to play, but need to be underpinned by more far-reaching and systematic changes" (p. 554). From a systemic perspective, it is vital to develop an institutional culture allowing all individuals to advocate for themselves and one another. Patriarchal cultures and systems established in institutions of higher education tend to emphasize individualistic and competitive environments that pit faculty against one another, rather than promote support for the common good. For instance, faculty evaluation is often based on individual performance in research, teaching, and service, where research tends to be weighed more heavily than the other two criteria. Research is often evaluated based on one's publication record, where solo authorship carries a greater weight than the collaborative co-authored publications; whereas, collaborative efforts are generally a more common and comfortable way for women to work (Holman et al., 2018). Faculty work and efforts related to supporting mentorship are often placed in the category of "service," which is even less valued. To effect change, the faculty-evaluation system should hold in higher regard work encouraging the common good. Initiatives such as mentoring women, as well as other underrepresented individuals in STEM, merits greater weight in the evaluation system.

Systemic initiatives grounded in a critical feminist lens take a proactive stance to addressing inequities. Quite often, those with less power or who are marginalized shoulder the burden of (and retribution for) calling attention to issues of hegemony. Exemplary institutions enable forward-thinking leaders to proactively address inequalities existing in the system. These institutions also implement clearly articulated family-leave policies and accommodations supporting women such as lactation rooms and flexible meeting schedules (Lodish, 2015).

Faculty and staff governance is another domain where institutions of higher education can improve – specifically, by adding the establishment of mentorship programs, an inclusive campus culture, and a working environment to the agenda of topics for discussion and action. Many institutions of higher education are often faculty governed, with a term-appointed faculty senate. In many cases, the senate is empowered to act for the university faculty in all matters pertaining to the immediate government of the university. Institutional governance must address issues of institutional disproportion and imbalance in ways supporting efforts to promote diversity, equity, inclusion, and broadened participation.

6.4 | Subsequent research

While the STEM mentoring literature places emphasis on leveling the playing field for women and increasing their participation in STEM fields, more research is needed to move beyond an “add women and stir” approach (Heybach & Pickup, 2017; Martin, 2003; Noddings, 2001), to interrogating whether these mentoring programs disrupt the isolating and exclusionary practices that created the gender imbalance and STEM crisis to begin with (Mansfield et al., 2014). Moreover, additional research in the STEM mentoring literature is needed to explore the experiences of non-white and underprivileged women, and the ways various forms of oppression (not just gender) are in separately connected to create systems of domination for all women (Biana, 2020; Wildman, 2007). Such work could also explore the inter-cultural issues among women as well as the nuanced experiences that differ between white women, indigenous, and women of color, and the subsequent mentoring, policies, and practices that are needed to address their diverse needs and challenges.

7 | CONCLUSION

In this paper, we argue that a critical feminist lens allows us to highlight the voices, experiences, and perspectives of women who are marginalized in male-dominated STEM fields. In particular, this framework allows us to pay close attention to the ways women's experiences tell a similar recurring narrative over the past 35 years about gender inequality, tokenism, and gendered segregation in the workplace (Seron et al., 2018; Tonso, 2014), and critically examine programs (e.g., mentoring) aimed to reduce these structural barriers for the recruitment and retention of women in STEM. Throughout our review, we also tackle many STEM education and career-related gender equity issues faced by women globally. Our hope is to ascertain best practices for closing the STEM gender gap.

It is crucial for employers and educational systems to acknowledge the disparities and barriers women encounter as they pursue STEM careers in a male-dominated environment, and to provide support in terms of workplace/campus policies, training, and mentoring. Mentoring for women in male-dominated STEM fields include peer mentoring (horizontal mentoring), role modeling, one-on-one vertical mentoring (dyad), and group-facilitated mentoring. These mentoring programs have provided both mentors and mentees with inspiration and guidance, career advice in establishing goals and recognizing opportunities, work-life balance and integration, personal and emotional support, gender bias acknowledgment, and access to networking and scholarly opportunities (Dennehy & Dasgupta, 2017; Welch et al., 2012).

Some would argue the very idea of gender equity measures targeting women can preserve how “femininity and masculinity” is valued in male dominated organizations, and fail to disrupt the status quo. While this can prove true with band-aid programmatic approaches, we believe that the complex task of organizational change can be achieved when mentoring programs utilize a critical feminist lens. In this vein, program developers have three critical areas to consider when initiating a new STEM mentoring program: (1) the culture of their institution, (2) the individuals they serve, and (3) the role they intend to play as program developers.

The larger institutional focus should examine the culture of the institute and ways the program goals are designed to disrupt the status quo. This includes the deep-seated assumptions that members of the organization hold about gender inequity, the assumptions reflected and maintained within the cultural fabric of the organization, and how these assumptions are legitimated by rewards, merit increases, or progress reports and evaluations (Meyerson & Kolb, 2000). When designing and implementing mentoring programs, developers should consider programmatic aims to place women in empowered positions to advocate for themselves in instances of discrimination, chauvinism, racism, and sexism. Furthermore, programs can bring together the institutional resources that support and foster the resilience of women who find themselves isolated in their departments. Lastly, program developers should reflect on how they intend to stand in the cross fires to ensure they are intersectional activists (Moradi & Grzanka, 2017) for those who experience discrimination. These are long standing systemic problems that cannot rely solely on mentoring

programs for resolution, but rather demand greater systemic commitment to institutional policies promoting social change.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Makini Beck  <https://orcid.org/0000-0002-7371-8633>

Jillian Cadwell  <https://orcid.org/0000-0003-4102-5389>

Ke Wu  <https://orcid.org/0000-0001-7645-9051>

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AUTHOR BIOGRAPHIES

Makini Beck, Ph.D., is an assistant professor in the School of Individualized Study and the Department of Sociology and Anthropology at Rochester Institute of Technology. She focuses her academic inquiry on immigrant women teachers in the U.S., mentoring women of color in academia, narrative inquiry, and autoethnographic research methods. She has presented her research at various national and international conferences, and has published her work in handbook chapters and peer-reviewed journals such as *Mentoring & Tutoring: Partnership in Learning*, and *NASPA Journal about Women in Higher Education*.

Jillian R. Cadwell, Ph.D, is an adjunct professor in the department of Civil Engineering at Washington State University Tri-Cities (WSU-TC). She has served as a WSU-TC STEM Outreach consultant and summer STEM camps director. She is co-chair of Million Women Mentors-Washington (MWM-WA) – a national initiative supporting the engagement of STEM mentors and female mentees. Dr. Cadwell's research incorporates an interdisciplinary study of mentoring models providing a cohesive system of support for females pursuing STEM pathways. Additionally, she has consulted on the NSF-ITEST project *Back to the Earth* (NSF#1139657), which engages Tribal youth and communities in culturally focused, content-rich STEM knowledge that aligns with place-based pedagogies.

Anne L. Kern, Ph.D., is a professor in curriculum/instruction and science education at the University of Idaho. Her research focuses on STEM education, specifically the integration of STEM and culture to support learning STEM content, particularly for Native American students and communities. She writes in the areas of STEM education, learning, and mentoring. She is the principal investigator or co-PI for several federally (e.g., NSF, NASA, and DoE) funded projects, to support initiatives in STEM education. Before her work in education, she worked for 15 years in chemistry research focused on environment and fate assessment modeling.

Ke Wu, Ph.D., is a professor in mathematics education at the University of Montana. Her research focuses on statistics education, statistical modeling, and mentorship. She is passionate about working with and for underserved peoples and communities. Her work in recent years emphasized exploring social, psychological, and systemic aspects of diverse students and faculty success in STEM. She has been principal investigator for several projects funded by agencies such as the National Science Foundation.

Maniphone Dickerson, Ph.D., is the Dean of Business and Workforce Development at Evergreen Valley College. She is the Regional Vice President of the San Francisco/Bay Area for the California Community College Association of Occupational Educators. Her research focuses are mentoring, career education, and workforce technical skills for STEM occupations. She is committed to conducting research and advocacy work that aims to decrease the gender and equity disparities in male dominated occupations. She is the principal investigator for an ANNIPIS grant to support more Southeast Asian American Students into STEM occupations and other high demand high wage careers.

Melinda Howard, Ph.D., is a faculty lecturer in the Biology Department at Gonzaga University. Her research focuses on equitable STEM education, including culturally-relevant STEM pedagogy and programs. She is interested in the cultural, social, and epistemological dynamics that interface between teachers, students, and learning opportunities within formal and informal STEM educational programs, particularly in how they influence pathways for Indigenous students.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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