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The Status of Women in STEM in Higher Education: A Review of the Literature 2007–2017

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ABSTRACT
Increased efforts to diversify science, technology, engineering, and mathematics (STEM) education in the United States have drastically increased the number of studies offering insight into the experiences of women in STEM programs in higher education. This paper presents a thematic review of the literature regarding their status from 2007 to 2017 including journals, trade magazines, theses, and dissertations. It focuses on areas of recruitment, retention, barriers, and faculty issues. Stereotypes, biases, campus culture, classroom experiences, identity, and sense of belonging are also explored. The author additionally identifies gaps and suggests related areas for new research as well as implications for librarians.

KEYWORDS
Academic libraries; engineering; mathematics; science; STEM; technology; women

Introduction

The proliferation of interest regarding science, technology, engineering, and mathematics (STEM) education in the United States (US) in recent years has had a tremendous impact on the literature generated on this topic. In recent years, the spotlight on STEM education (pre-school through higher education) has given rise to hundreds of studies ranging from the recruitment and retention of women students to the workplace climate of women faculty and staff. These new studies have increased the demand for up-to-date research and information for professionals, researchers, and administrators. This review will help librarians understand the needs of students, faculty, staff, researchers, and administrators that support women in STEM in higher education. This paper presents a brief background about recent developments in STEM education followed by a thematic review of the literature including journals, trade magazines, theses, and dissertations. It focuses on the status of women from 2007 to 2017 including community colleges as well as university programs.

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Government support for STEM

Due to high demand from many public and industry constituents, the U.S. Congress passed the America Competes Act in 2007 to invest in STEM research and education for students from kindergarten to graduate school. Congress reauthorized the act 3 years later with the America Competes Reauthorization Act (2010) with additional stipulations to increase the number of underrepresented minorities (URM) in STEM fields (Gonzales 2015). In 2009, President Barack Obama launched the Educate to Innovate campaign to enhance the status of the United States as a global leader in science and mathematics education over the next decade so American students would no longer be outperformed by those in other nations. One of the three overarching priorities for this campaign was specifically "expanding STEM education and career opportunities for underrepresented groups, including women and minorities" (Office of the Press Secretary 2010, para. 11).

More than ever before, women have been encouraged to study and excel in STEM (Corbett and Hill 2015). Yet the dramatic increase in their educational achievements in STEM fields has not been matched by similar increases in the overall representation of women in these fields. Women and minorities comprise 70% of college students but less than 45% of STEM degrees (Office of Science and Technology Policy 2016). The representation of women in STEM matters. Diversity in the workforce contributes to creativity, productivity, innovation, and success. "Women's experiences—along with men's experiences—should inform and guide the direction of engineering and technical innovation" (Corbett and Hill 2015, 92). Higher education is in the spotlight to produce graduates to fill the predicted 2.4 million STEM jobs anticipated by 2018 in the United States (Office of Science and Technology Policy 2016).

Implications for librarians

As colleges and universities strive for gender equity in STEM programs, libraries must ensure their collections adequately reflect the needs and populations of their campuses. Librarians have an obligation to select and support the access to materials on subjects that meet the needs, interests, and abilities of all persons in the community they serve. Since there is a national effort to recruit and retain women in certain disciplines, the collection should reflect this topic. Traditionally, most library collections reflect the majority white male population that has dominated the STEM fields for centuries and tell the stories of women as a minority voice, if at all (Palumbo 2016). Collection development should mindfully focus on sources that grant students, faculty, and staff access to historic and contemporary narratives about women in STEM based on these important themes in the literature. Patrons will gain a broader understanding of how men and women have shaped these fields and they may explore new topics due to the availability of alternatives

(Davis 2014). Libraries may be called upon to provide sources about women in STEM for campus strategic planning, outreach, recruitment, or grant writing for groups on campus. By understanding the issues surrounding the status of women in STEM in higher education, librarians can help their institutions prepare to engage fully in local, regional, and national efforts.

Literature

This paper provides an overview of how this topic is currently treated by researchers concerned with the status of women in STEM in higher education. The intersectionality of the topic necessitated article selection from concentrations such as psychology, gender studies, cultural studies, education, science, technology, engineering, and mathematics. This literature review is necessarily selective and focuses mainly on peer-reviewed journals and trade publications published between 2007 and 2017. OCLC Worldcat, Google Scholar, and commercial packages including Web of Knowledge, EBSCO, ProQuest, ProQuest Dissertations and Theses, and ScienceDirect were used for information retrieval. Select government reports and documents were reviewed but ultimately not included due to the tertiary nature of the information. While the author did review OCLC and Amazon for books regarding this topic, the scant literature available led to their exclusion. However, one publication medium that has been relatively ignored but is included here is dissertations and theses. These studies are frequently as useful for their current literature reviews as they are for their results. Additionally, they provide timely recommendations for further areas of study because of the rapid nature of their dissemination. Through local holdings, open access sources, and interlibrary loan services, approximately 1039 articles and dissertations were acquired and reviewed. Themes emerged around recruitment, retention, barriers, and faculty issues. Stereotypes, biases, campus culture, classroom experiences, identity, and sense of belonging were also reflected in the literature.

Recruitment

The recruitment of women to STEM has historically been a long, drawn-out endeavor. A variety of causes have contributed to failed recruitment efforts (Wang and Degol 2016), including social factors (Cho et al. 2009; Lyon 2013; Thackeray 2016), institutional structures (Bottia et al. 2015), poor advising (Lee 2008), and early education classroom environments (Han 2016). However, studies show that developing an identity linked to STEM from a young age (Bieri Buschor et al. 2014; McCarthy and Berger 2008), having supportive families (Burge 2013; Lee 2016; Lyon 2013), access to quality advising (Byars-Winston 2014; Bystydzienski, Eisenhart, and Bruning 2015), and exposure to gender-inclusive video games (Bonner 2015;

Borghetti 2014; Gilliam et al. 2017) can all play a part in the choice to pursue a career in these disciplines before enrolling on college.

While it is possible to explore and change majors after enrolling, studies suggest early exposure can be a precursor to pursuing certain careers (Bishop 2015). Advocates for improving gender diversity often focus interventions on increasing interest in the fields among elementary and middle school students (Valla and Williams 2012). By kindergarten, gender differences in attitudes toward and expectations about mathematics careers and ability are evident (Ceci et al. 2014). According to Speer (2017), gender gaps in test scores, specifically science and mechanical subjects, are present in teenagers by age of 15 years suggesting women and men do not enter college with identical skills. Exposure to STEM areas through exploratory science and mathematics courses during high school can positively influence women to declare a STEM major (Maltese and Tai 2011; Morgan, Gelbgiser, and Weeden 2013; Redmond-Sanogo, Angle, and Davis 2016) as well as through taking advanced placement (AP) classes (Hoepner 2010), participating in out-of-school programming (Ault 2008; Edzie 2014), and interacting with influential women mathematics and science high school instructors (Bottia et al. 2015; Conklin 2015). Likewise, attending a STEM-focused school can enhance interest in science and mathematics careers (Liggett 2014; McKnight 2016; Means et al. 2016) as well as positively viewing science as a career before college in general (Conrad 2009; Heilbronner 2011; Sadler et al. 2012; Sax et al. 2017). Four recruitment subthemes emerged in the literature and are discussed below.

Motivations for career choice

Motivation to pursue a STEM career was the largest subtheme in the recruitment literature. This comes as no surprise since the nature of recruitment has stakeholders in and outside of institutions trying to increase women student enrollment (Franchetti, Ravn, and Kuntz 2010). Industry leaders have a high demand for skilled employees (Bottia et al. 2015) and disciplines want to ensure their research continues to expand and grow through the newest generation of freshly minted professionals. Likewise, the United States as a whole has a large stake in continuing to be a world leader in technology and science expansion (National Science Foundation 2017).

Current studies show women are motivated to consider STEM careers by a significant amount of personal interest in STEM aspects (Le and Robbins 2016) such as careers that highlight communal goals or helping others (Diekman et al. 2010, 2017; Diekman, Weisgram, and Belanger 2015; Edzie 2014; Fuselier and Jackson 2010) and where they can work with people (Su and Rounds 2015). Studies also suggest that there are similar and different motivations for women minorities (Kolo 2016). For example, Ray (2016) reports that African American women were more likely to be influenced by the reputation of the university, religious leaders, and their confidence in their abilities in science and mathematics than their non-African American peers were.

Pipeline

Sue Berryman (1983) first coined the phrase the STEM pipeline but this moniker describing the bigger picture of STEM recruitment as a series of longitudinal steps has recently regained traction in the literature (Doerschuk et al. 2016). Petersen (2014) suggests that both formal and informal K–12 classroom experiences engaging in STEM activities, access to volunteer and mentor opportunities, and building strong self-efficacy lead to a smooth STEM pipeline. Ideally, young women are being engaged with STEM in both primary and secondary school education, decide to enroll as STEM majors in higher education, and then flow right into STEM careers.

The STEM pipeline metaphor has been criticized (Cannady, Greenwald, and Harris 2014; Miller and Wai 2015) and its appropriateness questioned (Ceci et al. 2014). There are now suggestions that the recruitment efforts should shift to certain subdisciplines of STEM (Heilbronner 2009) and focus specifically on computer science, engineering, and physics pipelines due to larger gender gaps (Lehman, Sax, and Zimmerman 2017; Sax et al. 2016; Su and Rounds 2015). Campbell (2011, 310) proposes a new model "Sequence of Life Events Leading to Career Choices," providing a linear progression which maps out a career path from grade school through career. The leaky pipeline is a metaphor for the greater likelihood for women to leave STEM fields at every point, from recruitment to attrition after graduation (Goulden, Mason, and Frasch 2011), in the private sector (Harris 2015) or as faculty members (Chesler et al. 2010; Gibbs et al. 2014); because of a significant amount of barriers. These barriers are discussed further later in this paper.

Pathways

As an alternative to the one-size-fits-all systematic approach of the STEM pipeline, the more-indirect pathways students take are also of interest (Cannady, Greenwald, and Harris 2014). Wang and Degol (2013, 305) provide the definition as "the STEM pathway is composed of a series of choices and achievements that commence in childhood and adolescence." It is not enough to simply spark early interest in STEM areas (Seaton 2011, 6) or ensure a strong belief in mathematical ability (Nix, Perez-Felkner, and Thomas 2015; Perez-Felkneri, Nix, and Thomas 2017) before students consider a STEM career. Institutions must follow up on these pathways with gender-neutral recruitment messages (Krome 2016) showing current and prospective STEM students that they will have every opportunity to succeed with strong messages supporting themes of inclusiveness of gender, race, and privilege (Osei-Kofi and Torres 2015). Substantial financial resources, educational support, and social support must be offered to help students transition, particularly for URM students (Bystydzienski, Eisenhart, and Bruning 2015; Rosa 2013).

Two-year transfers

Historically, community colleges have enrolled large numbers of women as well as attracting displaced workers and postsecondary students who are older (Hagedorn and Purnamasari 2012). Two-year programs and transferring credits have become a popular topic in the literature as the skyrocketing cost of higher education leaves students scrambling for more economical means of reaching their goals, such as enrolling in either online courses (Wladis, Hachey, and Conway 2015) or face-to-face courses (Wang 2016) at community colleges. Surprisingly, Wang (2013) reports that while high school exposure to mathematics and science courses appears to be a strong influence on students seeking a 4-year STEM degree, the impact on community college beginners' STEM interests is much smaller.

The success of the academic adjustment of STEM students to a 4-year institution is influenced by previous experiences with faculty and staff (Bohanna 2016; Zamudio 2015), interactions with advisors (Jorstad 2015), exposure to role models and mentors (Edwards 2015), the intent to transfer (Wang et al. 2017), support systems (Jackson 2013), and the overall experience of the transfer process (Jackson 2010). Students may face setbacks in the transfer process due to dissatisfactory advising or imperfect program alignment with the courses they have already taken (Packard, Gagnon, and Senas 2012). Students may transfer credits to STEM residential or online programs (Drew et al. 2016) to complete their bachelor degrees, and institutions would be wise to recognize the importance of additional life experience as a support, rather than a barrier, to the transfer process (Wickersham and Wang 2016).

Retention

Once students are enrolled as STEM majors, there must be sufficient effort to retain students (Corbett and Hill 2015). Traditionally, institutions focus primarily on recruitment and little on what to do with women once they arrive on campus to ensure degree completion. However, Corbett and Hill (2015, 92) note: "recruiting women will be truly successful only if women who start in engineering and computing stay in these fields." While exemplary high school grades and choosing to enroll in STEM programs early on are important influences for progressing through a program (Rask 2010), this is not enough to stop the leaking STEM pipeline (Gayles and Ampaw 2014). O'Donnell and Cunningham (2015) recommend interactive engagement with students during class, psychological interventions, tutoring programs within the university or department, and a nation-wide online tutoring program to ensure women in STEM have the support they need to succeed. Retention efforts should also include encouraging faculty attitudes and support (Blair et al. 2017, 14–43; Gayles and Ampaw 2011; Santiago 2012), the presence of more women faculty in the department, and undergraduate research experiences (Vieyra, Gilmore, and Timmerman 2011; Wilker 2017). Tutoring can also play a large role in retention, and Robinson (2007) found that first-year women were more likely to achieve a mid-level or high-level mathematics-oriented major if they regularly made use of mathematics tutoring. Additional research is needed to assess how and where these interventions and retention strategies are most likely to be beneficial to women students.

Learning communities

One of the emerging methods of encouraging student retention has been a focus on creating learning communities and opportunities outside the classroom to support women in STEM. These efforts include peer mentors (Stout, Dasgupta, Hunsinger, and McManus 2011; McCullough 2016), living-learning residential programs with social and curricular ties (Dagley et al. 2016; Grays 2013; Inkelas 2011; Maltby et al. 2016; Ramsey, Betz, and Sekaquaptewa 2013; Soldner et al. 2012; Szelényi, Denson, and Inkelas 2013; Szelényi and Inkelas 2011), residential halls for designated majors (Pistilli 2009), all-women colleges (Brand and Kasarda 2014), and partnerships between colleges and high schools to provide a connection to STEM students (Finkel 2017). Summer bridge programs also foster a connection to the program and the institution (Lane 2015).

Mentoring/role models for students

In addition to providing residential communities for peer-to-peer support, the time-honored methods of mentoring and role models are well documented in the literature (Barker-Williams 2017). Women role models strengthen young women's mathematics attitudes and self-concepts and increase women's abilities to consider STEM fields as career options (Cheryan et al. 2011; Corbett and Hill 2015). Leavey (2016) reports that women in STEM prefer to have women mentors but do not differ in types of mentoring needed compared with male peers. This supports research conducted by Shin, Levy, and London (2016) where women reported an increase in perceived fit in STEM after reading biographies of successful STEM role models who were also women and findings from Herrmann et al. (2016) where women were more likely to persist in STEM courses after reading letters of encouragement from women role models. Aside from traditional one-on-one mentoring programs (Carpi et al. 2017), there are also successful mentoring groups specifically for minority groups (Katz et al. 2017; Snead-McDaniel 2010), and communal mentors (Fuesting and Diekman 2017).

Persistence

The ability of women to persist in STEM disciplines appears to be a new take on the study of student retention. Moving on from predicting whether women were likely to leave STEM programs (Riegle-Crumb, King, and Moore 2016; Simpson and Maltese 2017) and using academic predictors based on precollege performance indicators (Beekman and Ober 2015), this emerging body of research focuses on collecting information from the women themselves. Persistence for women in STEM programs relies on a variety of internal (micro) and external (macro) levels of support (Rice and Alfred 2014; Shapiro and Sax 2011) and has been linked to numerous factors.

A woman's persistence in STEM has been linked to her internal motivation or commitment (McPherson 2012; O'Connor 2014), career adaptability (Murray 2016), and when the persistence attitudes begin (Ma 2011). Students are also likely to persist if they have perceived support from advisors (Clark et al. 2016; Prime et al. 2015), adequate precollege education (Ceglie and Settlage 2016; Riegle-Crumb et al. 2012), high performance in the classroom (Lang 2008; Milesi et al. 2017), and a resilience toward gender stereotypes in STEM (Di Bella and Crisp 2016). Support from family (Hughes 2010; Robinson 2012; Talley and Martinez Ortiz 2017), romantic partners (Barth, Dunlap, and Chappetta 2016), the campus community (Morganson et al. 2015; Pedone 2016), and a strong women peer group (Morganson, Jones, and Major 2010; Robnett 2016; Shapiro 2011; Stine 2010) can also aid in women persisting in STEM. Le and Robbins (2016) also found that women were more likely to persist in engineering programs if they had already experienced strong intentions to persist in previous situations. Students' socio-economic backgrounds (Kerr et al. 2012) and having college-educated parents also increased the likelihood of persistence (George-Jackson 2014). Espinosa (2011) reports that URM students persisting in STEM engaged with peers, joined student organizations, participated in undergraduate research programs, and attended institutions with a robust community of STEM students.

During the review of the literature, the idea of what makes a woman successful in STEM in higher education was a surprising topic that rose to the surface. The word success was repeatedly used in a variety of contexts. Success was both defined (Charlevoix-Romine 2008) and sought after (Meyer, Cimpian, and Leslie 2015). Studies want to know why women are successful on campus as faculty (Olund 2012) and for degree completion (George-Jackson 2009). Success for women in underrepresented groups (Alexander Nealy 2017; Charleston et al. 2014) is a growing area of literature as well. It is not enough that women persist through programs and quietly graduate; they must be successful (Whalen and Shelley 2010). This growing interest may be correlated to the significant amount of financial and time commitments made for recruiting and retaining women as a justification for institutions. No such defined or examined interest in success for men in STEM was found in this literature review. More studies are needed and the literature must be expanded to understand this obsession with success.

Barriers

Despite the numerous studies exploring the persistence and success of women in STEM fields in higher education through numerous increased support systems, there are still many barriers that may come between a student and degree completion (Fouad et al. 2010), especially for women first-generation students, transfer students, students from different socioeconomic backgrounds, and URM students. The intersectionality of race, gender, ethnicity, and socioeconomic backgrounds makes it extremely difficult to talk about one barrier without talking about several because students are multidimensional in their experiences, identities, and backgrounds. New research is needed on these factors; for example, race, ethnicity, and/or gender and how those intersect with social class, sexual orientation, ability, and/or religion. While acknowledging these complexities and nuances need more in-depth discussion than space allows here, this review will cover some of the overarching barriers that appear to affect women in STEM in general.

One of the biggest barriers to STEM programs is the continuous perception as male-dominated (Lee 2008), and this system contributes to a lack of interest in these programs through psychological barriers from the media, the ability beliefs of teachers, and parents and peers (Saucerman and Vasquez 2014). Studies suggest barriers also include affordability and availability of programs (Engberg and Wolniak 2013; Packard et al. 2011), making initial career choices based on little or no data (Iskander et al. 2013) or in isolation (Chaudhuri 2011; Thackeray 2016).

An emerging theme in this area of research is that of a "chilly climate," at a department, college, or institutional level. Seaton (2011, 6) defines a climate as chilly "when individuals within an environment are not treated equally or fairly." Studies show women in STEM face additional stereotypes, discrimination, biases, cold campus climates, and stifling classroom experiences as part of their lived experiences (Johnson 2007; Kuntz 2009; Litzler 2010; Walton et al. 2015). Johnson (2012) found a positive campus racial climate was significantly correlated to a sense of belonging for African American, Asian Pacific American, and multiracial/multiethnic women.

Stereotypes

Occupational segregation and affiliated stereotypes are strong influences on career development. Stereotypes about people who are interested in STEM abound in popular culture, making it one of the largest barriers for women (Moss-Racusin, Molenda, and Cramer 2015; Ryan 2014). Women in STEM face gender stereotypes at both community colleges (Kincaid 2015) and universities (Schneider 2010; Stout, Grunberg, and Ito 2016). Because of the long-standing sociocultural stereotypes regarding successful cisgender white males and academic STEM disciplines, women face a phenomenon known as stereotype threat (Chase 2012; Corbett and Hill 2015). Stereotype threat occurs when individuals fear that they will confirm a negative stereotype about a group to which they belong (Cheryan, Master, and Meltzoff

2015; Cheryan et al. 2017; Jones, Ruff, and Paretti 2013; Stamm 2009) and has been linked to higher levels of anxiety and stress in women (Nguyen 2016; Rice et al. 2015) and women minority students (Beasley and Fischer 2012). This threat is documented in women's performances in masculine-stereotyped occupations (Barth et al. 2015; O'Brien et al. 2015a; Ramsey 2011; Smyth and Nosek 2015) and within the field of computer science in particular (Cheryan et al. 2013; Master, Cheryan, and Meltzoff 2016; Thackeray 2016). Extensive research has been done on the effect of stereotype threat in the classroom but research is needed on how it affects women in the classroom as a work environment (Corbett and Hill 2015).

Another well-documented stereotype women in STEM face is the cultural stereotype regarding women and weak mathematics ability (Bench et al. 2015; Luong and Knobloch-Westerwick 2017; Rea 2015; Shaffer, Marx, and Prislin 2013; Shapiro and Williams 2012; Thoman et al. 2008). Park et al. (2016) even found women (but not men) were more likely to show worse mathematics performance and less interest in STEM careers to seem desirable when pursuing smarter romantic partners on campus. Women in STEM also face stereotypes regarding appearances and behavior, whereas by appearing too feminine they signal they may not be well suited for science (Banchefsky et al. 2016.) and choosing to play up or downplay their gender as a way to adjust their gender depending on the environment, situational context, and immediate goals (Goldman 2010).

Biases

Major themes in the literature were the barriers of biases and sexism and were expressed through three subthemes: campus culture, classroom experiences, and lived experiences. Cultural stereotypes shape gender biases and influence interpersonal interactions within institutions. How we view and treat others, actions that may be taken or ignored, all steer us toward careers or away from others. "While explicit gender bias—that is, self-reported bias—is declining, implicit or unconscious gender bias remains widespread" (Corbett and Hill 2015). Implicit bias is usually thought to affect individual behaviors, but it can also influence institutional practices and structures (Handelsman and Sakraney 2015). Sexism and threats to masculinity within STEM fields (Hall 2016) become exemplified through the reluctance to accept evidence of gender biases (Handley et al. 2015), opposition to gender diversity initiatives in STEM (Danbold and Huo 2017), and exclusionary intentions toward women. Biases are also evident through the explicit endorsement of stereotypes about women in STEM (Jackson, Hillard, and Schneider 2014), the attribution of setbacks to abilities rather than external circumstances (LaCosse, Sekaquaptewa, and Bennett 2016), and women perceiving a lack of power to influence others (Chen and Moons 2015). Sexism and gender role stereotyping can also come through subtle insults (microaggressions), sexual harassment, or overt discouragement (Barthelemy, McCormick, and Henderson 2016).

Campus culture

If biases are found across an institutional level, the campus culture or departmental climate can itself serve as a barrier (Hurlock 2014). They may appear in administrative polices (Bancroft 2014; Hopewell et al. 2009), lack of undergraduate research opportunities (Hernandez et al. 2013), lack of diversity (Vazquez-Akim 2014), or class size (Fischer 2017). Women reported heavy course loads, lack of connection between material and application, and perceived lack of academic skills as barriers to completion (Vazquez-Akim 2014). Curricular constraints in majors may also enhance gender differences in STEM majors. Mann and DiPrete (2013) suggest that women are more likely than men on average have stronger preferences for a liberal arts curriculum and that they are therefore more likely to perceive their broader educational goals to be in conflict with the curricular requirements of certain STEM majors and occupations.

Classroom experiences

Interactions in the classroom can serve as a barrier on many levels. The physical environment of classrooms can make a difference in how comfortable a woman finds the overall learning environment (Corbett and Hill 2015). She may be the only woman in the class or one of a handful in the department and may have to acclimate to a traditionally masculine culture (Baxter 2010) or pay a femininity penalty (Simon, Wagner, and Killion 2017). Introductory classes purposefully designed to weed out students are more harmful to URM and women (Dabney and Tai 2014; Mervis 2011), and Shedlosky-Shoemaker and Fautch (2015) found women who felt demoralized in a competitive environment were more likely to switch majors. Even a syllabus, the first document a student encounters in the classroom which sets the tone for the course, can include gendered themes such as normalizing masculinity while disenfranchising other gendered identities (Bejerano and Bartosh 2015; Parson 2016a).

A student who dreads attending class or participating in a club may wonder if it is the peer group, instructor (Lester, Yamanaka, and Struthers 2016), or her own skill set (Litzler, Samuelson, and Lorah 2014). Women may hesitate to ask questions in class (Sobel, Gilmartin, and Sankar 2016) or underestimate their own abilities when they may simply have different learning styles than those engaged in class (Deemer et al. 2014; Kulturel-Konak, Lou D'Allegro, and Dickinson 2011). Deemer (2015) suggests there is indirect evidence that women in laboratory classrooms with fewer men see greater motivation and a stronger sense of academic well-being in science majors. Ellis, Fosdick, and Rasmussen (2016) found that women were 1.5 times more likely to switch to a non-STEM major after taking Calculus I despite the same preparedness and career goals as male peers. Women start and end the term with significantly lower mathematical confidence compared with men. This suggests a lack of mathematical confidence, rather than a lack of mathematically ability, may be responsible for the high departure rate of women. Alternatively, a supportive instructor can cultivate a lab or project team culture that values, includes, and respects women to foster a strong sense of belonging (Clark et al. 2016; Sheltzer and Smith 2014) and can change student perceptions about the underrepresentation of women in STEM by including meaningful dialog in the classroom (Lock and Hazari 2016).

Lived experiences

The literature on the lived experiences of women in STEM in higher education is broad and deep in scope. Many sociocultural factors influence these experiences and more emphasis is now being placed on the holistic evaluation of women in STEM (Eddy and Brownell 2016). Numerous studies document the different experiences of undergraduate students (Adornato 2017; Dawson 2014; Dwyer 2014; Jaladanki 2016; Parson 2016b; Streets 2016), graduate students (Harsh, Maltese, and Tai 2012), Latinas (Carbajal 2015; Cruz 2010; Rosbottom 2016; Ruiz 2013; Vielma 2016), African Americans (Burnette 2013; Galloway 2012; Gladney 2016; Mack, Rankins, and Woodson 2013; Squires 2015; Wilkins 2014), and women athletes as STEM majors (Comeaux et al. 2017).

There is a significant body of research covering the lived experiences of URM women including African American, Asian American, and Latina women, as well as women from other racial and ethnic groups (Ong et al. 2011; Syed and Chemers 2011). In the classic report *The Double Bind: The Price of Being a Minority Woman in Science*, Malcom, Brown, and Hall (1976) used the term double bind to define the idea that women of color experience oppression and discrimination based on their race or ethnicity and gender as scientists, resulting in these women being the least recognized and valued among URM in STEM. Wu and Jing (2011) recently built upon this work by suggesting there is also a double bind for Asian women. A developing line of research is the exploration of the experiences of African American women in STEM at predominately white universities (Alexander and Hermann 2016; LaMotte 2016; McClendon 2012) and the experiences of African American women at historically black colleges and universities (HBCUs) (Borum and Walker 2011, 2012; Jenkins 2012; Perna et al. 2009; Wilson 2016). All of these studies capture a rich tapestry of the unique perspectives of participants as they navigate their academic careers (London, Rosenthal, and Gonzalez 2011). Documenting the experiences of Latinas at Hispanic serving institutions (HSI) (Martinez Ortiz and Sriraman 2015) is an underdeveloped area and additional studies could provide more insight into the needs of these women. Johnson (2011, 82) calls for increasing this literature through inclusive research practices, including "developing research designs that examine racial and ethnic differences, describing the racial and ethnic composition of samples, and considering issues of race and ethnicity in interpretation and discussion of the results, along with acknowledgment of the limitations associated with racially homogeneous samples."

Identity

The concept of science identity and how women strive to become valued members of the STEM disciplines (and particularly those who identify as URM) has recently developed as a stronger body of literature (Szelényi, Bresonis, and Mars 2016). A science identity positively influences the likelihood of seeking a career in science (Stets et al. 2017). Studies suggest women can overcome barriers such as stereotypes and bias by focusing on their individual identity, self-concept, self-efficacy, and a strong sense of community (Lee 2013). Women often report feeling that they do not belong in STEM because they encounter a variety of threats to their social identity, including sexism, stereotype threat, and concerns about fitting in (O'Brien et al. 2015b). They may be forced to experience disjointed academic, science, and personal identities when entering STEM disciplines, and this holds true particularly for URM women (Beals 2016; Mahfood 2014; Tran 2011).

A sense of belonging in a particular setting such as a classroom, lab, or academic discipline is associated with positive outcomes for individuals. Settles, O'Connor, and Stevie (2016) found chilly climate perceptions and identity interference were associated with lower perceptions of science performance, suggesting a stronger identity and well-being may contribute to better long-term performances in the classroom (Ahlqvist, London, and Rosenthal 2013). Ackerman, Kanfer, and Beier (2013) report that women who persist have substantially higher mathematics/science self-concepts and Sax et al. (2015) suggests that women's lower mathematics self-concept has become a weaker explanation for their underrepresentation in STEM. A strong STEM identity can be built up through support from family members (Howard 2016; Parker 2013), professional societies (Revelo Alonso 2015), and peers who model STEM interests (Ahlqvist 2014; Robnett 2013).

Self-efficacy refers to a judgment about one's ability to perform to or achieve at a designated level (Wise 2007). It can be conceptualized as either general or task-specific. A high sense of self-efficacy can lead to persistence in STEM majors (Aryee 2017; Hardin and Longhurst 2016), and outcome expectations can be influential in predicting self-efficacy (Falk 2015). Mentors (MacPhee, Farro, and Canetto 2013; Wise 2007), advisors, peers, and faculty (Hogue 2012) can all have a deep impact on the level of self-efficacy (Charleston and Leon 2016; Dugan et al. 2013). Gurski (2016) found that although women rated themselves lowest on their mathematics and science abilities, they rated themselves higher on critical thinking, problem-solving, and teamwork skills and suggests young women who persist have higher than average feelings of self-efficacy. Stereotype threat may interfere with self-efficacy levels (Whitson 2008) but more research must be done in this area.

Sense of belonging

Social experiences in the academic environment can play an important role in influencing women, particularly in their sense of belonging in the STEM fields (Seaton 2011, 6). Women may feel more pressure to conform to masculine norms, such as higher levels of competition, and must work harder to establish their claims of scientific authority to participate in STEM (Hirshfield 2011). The perception of having to exert additional effort than men to belong and succeed can decrease motivation to pursue the field (Smith et al. 2013). Women with a low sense of belonging in STEM may feel pulled toward non-STEM disciplines where the sense of belonging is higher (Thoman et al. 2013). Feeling a sense of community within a program (Rincón and George-Jackson 2016), the college (Lambertus 2010), or within the discipline itself (Ong 2005) is vital for the success of women. Women associate perceived identity compatibility and perceived social support with a greater sense of belonging in STEM and at their institution (Rosenthal et al. 2011).

Careers

The ultimate goal in student recruitment, retention, and graduation is to prepare a successful career force. There is a comprehensive body of literature regarding the recruitment and retention of women in STEM careers after graduation and these themes will not be discussed here. However, there are emerging themes in the literature regarding barriers within higher education in the early career phase of the STEM pipeline. Many career options may not be considered simply because they were unaware of these opportunities because job placement advertisements are not targeting women (Glass and Minnotte 2010; McNeely and Vlaicu 2010). Even when students are aware of career options, they may not seriously consider those options because women have inaccurate information regarding either the option itself, are undecided about their career plans, or they doubt their ability to achieve in that field (Schuster and Martiny 2016). Xu (2017) found that strong academic performance in major-related courses contributed to the increased likelihood of students working in STEM-related fields. An informative, supportive graduate program experience can lead to successful career trajectories in the end in both higher education and the private sector (Clark et al. 2016) but women who experience unsupportive graduate programs are less likely to view academia as a viable career (Morrison 2013).

Women have reported lack of social capital and increased energy spent managing role expectations including building legitimacy and being recognized as an authority figure (Amon 2017). Likewise, a traditionally masculine environment with gender or family biases can also provide a barrier for women's career paths (Case and Richley 2013; Gehringer 2015; Settles, O'Connor, and Yep 2016; Valentino et al. 2016). Lack of confidence to become a successful faculty member can lead to a rejection of this career by women in STEM majors, leading to a disparity in the number of women faculty (Jacquot 2009). Gender diversity would be most beneficial if women were equally represented in research teams (Bear and Woolley 2011).

Faculty issues

Women faculty in STEM disciplines face similar issues as their student counterparts (such as persistence; Opare (2012)) but also the intersectionality of academic, career-specific factors. These include gendered teaching loads (Carrigan, Quinn, and Riskin 2011), tenure and promotion (Soto 2014), work–family balance (Bachman 2011; Beddoes and Pawley 2014; Kachchaf et al. 2015; Myers 2015; O'Brien and Hebl 2008; Tanenbaum 2015; Su and Bozeman 2016), general institutional policies and procedures for support (Blackwell, Snyder, and Mavriplis 2009; Feeney, Bernal, and Bowman 2014; Karpman 2015; Settles et al. 2013), research (Cozzens 2008; Deemer, Mahoney, and Ball 2012; Hart 2016; Holleran et al. 2011; Howe, Juhas, and Herbers 2014), departmental policies (Holmes, Kasi Jackson, and Stoiko 2016), diverse hiring practices (Easley 2013; King 2013; Leggon 2010; Smith et al. 2015; Torres 2012; Williams and Ceci 2015), and burnout (Pedersen and Minnotte 2017; Xu 2008). McClelland and Holland (2015, 218) found male campus leaders who exhibit lower personal responsibility frequently described women faculty as the ones who should be responsible for initiating changes related to gender equity and their "choices" to have a family were obstacles to gender diversity in STEM. Goulden, Mason, and Frasch (2011) suggest institutions offer a full package of policies that support family–work life such as removing time-based criteria for fellowships and productivity assessments that do not acknowledge family events on career timing.

Additionally, administrators should support early-career mentoring (Avallone et al. 2013), "on-ramping" into academic careers (Carrigan et al. 2017), and leadership opportunities (McCullough 2011). Like the wealth of literature on mentoring students, there is an abundance of research on mentoring faculty. This mentoring can come from early-, mid-, and late-career opportunities, through formal and informal support networks on campus (Buzzanell et al. 2015; Gorman et al. 2010; Thomas, Bystydzienski, and Desai

2015), through associations (Saville 2014), national organizations (Xu and Martin 2011), or through personal connections. Women faculty may seek advice on publishing, grants, colleagues, work–family balance, or career advice in general (Feeney and Bernal 2010). Mentoring with the goal for advancing to leadership positions (O'Bannon et al. 2010; Yen et al. 2007) is also key for recruiting and retaining women in STEM in all levels of academia.

Biases targeting students have also been found to affect women faculty on many levels (Easterly and Ricard 2011). Rhoton (2011) speaks to women faculty distancing themselves through gendered barriers, such as disassociating with other women who appear stereotypically feminine, avoiding feminine practices, and even denying gender inequality in academia. Women draw on gender expectations from cultural, occupational, and organizational cues to distinguish themselves from other women to align with traditionally masculine occupational and organizational requirements (Rhoton 2009). Williams, Phillips, and Hall (2016) found African American, Latina, and Asian American women are all more likely to face stronger prescriptive gender bias, descriptive gender bias, and gender bias triggered by motherhood. Their survey found dramatic differences by race, notably that African American women were more likely than other women to report that they had to prove themselves more than their colleagues, that Asian American women scientists reported more pressure to behave in feminine ways (and more push-back if they did not), and Latina women were more likely to be called "angry" or "too emotional" if they behaved assertively (Williams, Phillips, and Hall 2016, 11). Linley and George-Jackson (2013) stress that STEM diversity initiatives must be institution-wide and that resources and support for faculty development on issues of diversity and difference must be supported.

Conclusion

Current status of women in STEM

The status of women in STEM in higher education is making great strides toward gender equality but has further to go to be considered elevated and stable. Support from higher education and the US government has led to strengthened efforts to recruit women and create a strong STEM pipeline. Women are motivated now more than ever by a variety of academic and co-curricular influences to choose STEM fields as careers. However, the reports of the lived experiences of students reveal stereotypes, biases, chilly campus cultures, unsteady identities, and a wavering sense of belonging that are still barriers for successful degree completion and career entry. In addition to these barriers, women faculty also report a collective lack of mentoring and supportive policies (particularly for work–life balance) leading to burnout.

Further research opportunities

Areas for further research should focus on recruitment, retention, and performance. In addition to the gaps previously mentioned throughout this article, longitudinal studies are needed to assess and understand the STEM achievement gap between the United States and other high-performing countries (Xie, Fang, and Shauman 2015). What are the economic returns to STEM education and how will they be measured? Will women still be motivated to choose STEM careers from the reasons mentioned here or will monetary returns eventually rise to the top of the list as career choices expand with scientific and technological advancements?

Aside from comparing test scores, graduation rates, and career placement, there continues to be a need to understand the holistic lived experiences of women in STEM, including intervention and retention strategies that lead to success. What can reduce a chilly campus climate? When and where do these strategies need to be in place to be most effective? Documenting the experiences of women in URM groups from all institutions, including community colleges, predominately-white universities, HBCUs and HSIs would give voices to traditionally marginalized groups. There was also scant literature documenting the experiences of the women in STEM in LGBTQIA communities and these experiences desperately need to be brought to light as well. Further research on women's identities and sense of belonging is needed as cultural changes shift away from biases and stereotypes.

Actions for libraries

As discussed earlier, librarians have an obligation to select and support access to materials on subjects that meet the needs of the community they serve. In addition to collections that reflect these needs, librarians can also provide research and programming support for women in STEM in higher education. STEM programming offered through public libraries for elementary students (Hopwood 2012; Myers and Huss 2013; Reighard, Torres-Crespo, and Vogel 2016), middle school students (Roberson 2015), and high school students (Anderton 2012; King 2016) has increased dramatically and subsequent STEAM (science, technology, engineering, arts, and mathematics) programming is also becoming a trend for these age groups (Koester 2014). Public libraries host such events as "science Saturdays, robot races, LEGO clubs, maker spaces, hands-on workshops, and museum-quality STEM exhibitions" (Public libraries and STEM 2016, 11). However, there has been little literature on how academic libraries are providing collection development, research support, and programming specifically for women in STEM (or STEAM) in higher education (Arrieta and Kern 2015).

Collection development

Collection development should mindfully focus on sources that support students, faculty, and staff in the classroom, in professional scholarship, and in campus initiatives. First, libraries should develop a plan to purchase materials by and for women in STEM. Consideration should be given to works that support women authors and feminist perspectives to provide a rich diversity to traditionally homogenous, masculine disciplines. STEM education is highly interdisciplinary so collaboration with education, gender studies, and psychology subject specialists (within the local organization or within a larger library system) could also provide additional resources and perspectives to support the joint development of interdisciplinary collections. Second, publishers should be encouraged to provide titles for topics regarding women in STEM, preferably by women in STEM. Librarians can make these preferences known to vendor representatives and at conferences. Finally, collections should be displayed and promoted regularly to drive patron access, whether in the library or in external exhibits around campus (Barr 2016).

Research support

Research support for women in STEM in higher education can help with retention of both students and faculty (O'Toole 2017). Not only does this outreach help position librarians as educators in the campus community but these activities also contribute to the institution's learning mission. There is a strong body of literature that supports information literacy as a skill that serves both undergraduate and graduate STEM students (Perry 2016; Simonsen, Sare, and Bankston 2017; Spackman 2007; Van Lacum, Ossevoort, and Goedhart 2014) and it will not be expanded on here. Librarians are embedded in courses throughout the semester (Ferrer-Vinent 2016; Mandernach and Reisner 2012; Pritchard 2010) and help scaffold curriculum (Mitchell 2014; Scarmozzino 2010). Although there is less research on one-on-one consultations and help with theses/dissertation literature research, both reference approaches can contribute to student success in the classroom (Stern 2008) and ultimately to higher graduation rates. Additionally, a librarian may present special workshops specifically to student organizations or clubs who are associated with women in STEM covering such topics as basic research skills, literature reviews, or citation managers as part of a meeting. Likewise, the librarian could present to a faculty research group (Wagner 2015) or host a workshop for a STEM faculty organization promoting resources. These could highlight services for faculty support such as aid with citation tracking, grant searching, impact factors, or other services. These research services can aid in women faculty retention and tenure. To network with these groups, librarians could sign up for women in STEM listservs on campus, attend organizational meetings or events, or join committees dedicated to serving women on campus. By connecting with these women, librarians can learn about current research being conducted on campus and provide support for the institution's research activities overall (MacKenzie 2014).

Programming

In addition to research support, librarians could also provide programming outreach to women in STEM. Attending speakers, lectures, or other events hosted by groups on campus offers a window into the organization's interests and provides an opportunity to co-sponsor future events. Librarians can highlight collections that supplement speaker topics or events hosted by these organizations or even host them in the library. Programming opportunities could also include tie-ins to youth camps hosted on campus, workshops by other departments, student club events, high school tours, or faculty research groups or communities of practice. These may include tours of makerspaces as part of high school tours, 3-D printer demonstrations for STEM youth summer camps, or database presentations for new faculty orientations. Displays, programming, and events can help pull forth acquisitions, encourage discovery, and spark dialogue. With the annual ebb and flow of new faculty and students on campus, libraries should continuously strive to highlight their collections and services as a visible demonstration of their support of the women in STEM in higher education.

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