Using Ecological Systems Theory to Examine the Underrepresentation of Black Women in STEM

Abstract

Keeping women in the science pipeline and increasing the number of underrepresented minority women succeeding in science, technology, engineering, and math (STEM) careers are crucial to the economic and social prosperity of the United States. This is especially true for Black women. A lack of racial and ethnic diversity persists in STEM education and industries; consequently, the development of Black women in STEM warrants further conceptualization. We acknowledge the interplay between gender, race, and ethnicity in access to STEM, more especially for Black women, as the focus of this conceptual paper. We use intersectionality to explore the underrepresentation of Black women in STEM while applying Bronfenbrenner's ecological systems theory as a holistic context to understand the current causes of this persistent problem with the intention of illuminating research gaps worthy of additional exploration. This holistic conceptual model reinforces the consideration of process, person, environment, and time in research designs, across the five systems—micro, meso, exo, macro, and chrono—that function jointly to either promote or hinder the participation of Black women in STEM fields. Further conclusions and implications are fully discussed to enhance access pathways and equal representation.

Keywords: ecological system; STEM gender gap; Black women; ontological; microsystem; mesosystem; macrosystem; chronosystem

Introduction

The concern about the gender gap and the underrepresentation of African American women in science, technology, engineering, and math (STEM) careers is related to gender diversity, equity, social justice, and the "correct use of social and individual investment in human capital, talent, socio-economic development, and competitiveness" (Avolio et al., 2020, p. 774). Organizations that embrace gender diversity, according to Settles (2014), are associated with improved productivity and creativity, translating to increased profits. In addition, several researchers, such as Fuller et al. (2021) and Cheryan et al. (2013), have pointed out the positive influence of diversity on the growth of societies, replacing stagnation and homogeneity with innovation and creativity.

If achieving creativity through diversity provides insufficient motivation, consider that the United States is not producing and retaining "a sufficient number of STEM-related workers, researchers, and technicians" (Kozan et al., 2017, p. 206). Currently, the United States lags behind many other countries in the percentage of bachelor's degrees awarded in STEM fields (Basham et al., 2010; Perna et al., 2009; Rogers-Chapman, 2014). Relatively recent data indicated there are 8.65 million STEM job vacancies in the United States (Watson et al., 2020).

This deficit presents an existential threat to America's way of life in two ways. First, the standard of living is threatened by a lack of STEM workers, given that STEM employment is "essential for America's economic development and ability to compete internationally" (Alexander & Hermann, 2016, p. 308). The National Science Board (2015) agreed and reported that increasing the number of underrepresented minority women in STEM careers could help ameliorate a labor shortage in STEM fields, which in turn would sustain economic growth and improve international competitiveness. Second, since national security is "reliant on a complex synthesis of the people, knowledge, capital, and systems required to turn information into useful products—including weapons" (Brahm, 2021, para. 3), the nation's survival is at risk. Simply retaining the women of color who enter STEM educational programs in the STEM workforce, according to Alexander and Hermann (2016), would resolve the shortage of STEM workers and reduce the threat to U.S. economic and military security. As McGee and Bentley (2017) posed concerns with the way the STEM field positions the role of values such as equity, empathy, and altruism, they argued that STEM educators, researchers, and policymakers should understand how these values are integrated into, or diminished within, STEM fields because of research that implicates these principles as being relatively more important to underrepresented minority(URM) groups, such as Black and Latinx STEM students than to non-URM STEM students (see: Garibay

2015; Gibbs and Griffin 2013). Obviously, in the case of Black women, the problem is intersectional both related to gender and race.

Besides strong economic and national security arguments for creating more opportunities for underrepresented minority women in STEM, the relative lack of participation by Black women in STEM raises issues of gender diversity, equity, social justice, and economic progress and success (Avolio et al., 2020). Although in recent decades women have comprised the vast majority of medical and health sciences degrees and occupational roles, women continue to be underrepresented in math-intensive STEM fields. In 2012, women earned 59% of degrees in biological/biomedical sciences, 43% in mathematics and statistics, 18% in computer and information sciences, 19% in engineering, and 38% of degrees in physical and technological sciences (Cheryan et al., 2017; Wang & Degol, 2017). Commenting on this disparity, U.S. Deputy Secretary of Education Cindy Marten emphasized that the Department of Education's "Civil Rights Data Collection continues to demonstrate that students of color . . . are disproportionately excluded from learning opportunities in STEM" (U.S. Department of Education, 2022, para. 2). In a similar equity and social justice vein, Mim (2019) argued that female participation in STEM disciplines would not only reduce poverty and develop worldwide economies and infrastructure but also improve female health. As computer science and engineering provide "the highest economic returns" in education (Perez-Felkner, 2019, p. 11), getting more underrepresented minority women into those fields would help decrease poverty among them. Regarding health, Black women whose doctor is also Black are more satisfied with their medical care and have lower infant mortality rates than those without Black doctors (Fuller et al., 2021).

These concerns about a dearth of underrepresented minority women in STEM jobs are not meant to suggest efforts to improve their representation in STEM have been unsuccessful or ignored. Far from it. Women in the United States have increased their labor participation in STEM from 8% in 1970 to 27% in 2019, but that is still a far cry from their 48% representation in the labor force (Kuchynka et al., 2022). Money and research efforts have been directed toward the STEM gender and ethnic gap. The U.S. Department of Education (n.d.) invested close to a $1 billion in STEM education during Fiscal Year 2019–2020. In addition, STEM literature reviews by Kanny et al. (2014) and Avolio et al. (2020) found hundreds of articles on gender-based inequities in STEM over the last half-century.

Despite these exertions, however, a significant race and gender gap remains in STEM. The World Economic Forum reported “around 26% of jobs in the technology sector are carried out by women” (cited in Garcia-Holgado, 2020, p. 1824). The number of women earning degrees in some STEM fields actually dropped between 1993 and 2009, with a decrease of 4% in statistics and of 14% in computer science (Alexander & Hermann, 2016). Regarding women of color, Martinez and Christnacht (2021, as cited in Kuchynka et al., 2022) reported that whereas women represent 27% of STEM workers, just 5% are women of color. These racial disparities in STEM are a social justice issue and a cause for concern, given the growing consensus in the STEM community that rapid innovation and technological breakthroughs require a diversity of thought, talent, and people (McGee and Bentley, 2017, p.2).

Because children have multiple risk factors and multiple resources, looking at a single factor is unlikely to uncover a solution for improving STEM access for underrepresented minority women, according to Masten and Coatsworth (1998). More recently, Eddy and Brownell (2016) reached the same conclusion. Many of the studies in their review of gender disparities in STEM “report on only one type of data. More studies that collect multiple measures, longitudinally on the same sample of students, would provide us a more nuanced picture of student experiences in our majors and classrooms” (Eddy & Brownell, 2016, p. 10). While there are many potential reasons for the current lack of diversity in STEM, multiple studies have explored both the attrition and retention of Black students at multiple points along the STEM pathway, from high school education to industry employment (McGee and Bentley, 2017, p. 3). A lack of racial and ethnic diversity persists in STEM education and industries. Consequently, given the unique challenges of Black women in STEM, their advancement in the field warrants exploration through the eco-system lens. Therefore, our purpose in this conceptual paper is threefold: (1) to understand how the intersections of gender and race influence Black women’s underrepresentation in STEM majors and careers; (2) to highlight the plausible challenges facing Black women’s pathways and experience in STEM; (3) to suggest an eco-system conceptual framework for further understanding and enhancing Black women's representation in STEM.

Arising from the conjecture, greater insight about Black women’s underrepresentation in STEM can be understood through a systemic lens (Joseph et al., 2023). Therefore, we assert that using Bronfenbrenner’s (1977, 1988, 1994) ecological systems model is the best theoretical approach to understand where weaknesses occur in the field of research into STEM persistence. In other words, it might be time to refocus some energy from systems and topics that have garnered the most attention to other systems and topics that have not been studied seriously in order to increase the number of underrepresented minority women in STEM in general and how the intersections of gender and race influences Black women’s persistence in STEM in particular.

Given the racial disparities in STEM and the alarming underrepresentation of Black women in the STEM field, we adopted an intersectionality lens in problematizing the state of unequal representation. In this regard, in line with Ireland et al., (2018, p. 226) we argue that intersectionality is a theoretical and methodological framework by which education researchers can critically examine why and how students in STEM fields who are members of intersecting marginalized groups have distinctive experiences related to their social identities, other psychological processes, and educational outcomes (see: Cho et al., 2013; Collins and Bilge, 2016). In this regard, Crenshaw's (1989, 1991) discussion of intersectionality was to confront the inadequacy of one-dimensional antiracist and antidiscriminatory discourse in addressing the sociopolitical concerns of Black women (cited in Ireland et al., 2018, p. 231). Hence, this approach is centered on an examination of power and privilege (within and across groups) as well as attention to the personal, interpersonal, and structural significance of simultaneous social group membership. In this conceptual paper, we employ intersectionality as an analytical framework for conceptualizing the underrepresentation of Black women in STEM.

With the above picture and the history of underrepresentation of Black women within STEM disciplines (Coleman, 2021; Ireland et al., 2018; McGee, 2016), this conceptual paper contributes to our understanding of Black women's experience in STEM. It is our goal to inform activity needed to promote Black women in STEM programs.

In the following sections, we present first our main definitions, the 'conceptual synthesis' approach adopted as a methodological stance in understanding Black women's underrepresentation in STEM. We then present a literature synthesis with findings classified through the ecological model in order to problematize the notion of underrepresentation of Black women in STEM while posing our emerging framework. This is followed by a conceptualization of Black women in

STEM through ecological theory to increase the understanding of Black women's experience in STEM and enhance future policy and programs aiming at equitable representation.

Definitions

Part of the problem in doing research on female representation in STEM has to do with the fact that women do indeed dominate in some STEM fields. In the remainder of the paper, the use of the acronym STEM is meant to include only highly male-dominated disciplines where the highest levels of achievement are disproportionately underrepresented by women. Those disciplines include physical sciences (physics, chemistry), technology (computer science), engineering, and mathematics. Both applied and research sciences are included in the definition (Mullet et al., 2017). Even so, this representation of STEM education still fails to take into account the symbiotic nature of science, technology, engineering, and mathematics (Basham et al., 2010). Until educational practices change to account for the interconnectedness of fields of study, STEM is perhaps the best we can do.

Likewise, while this conceptual paper is focused on Black females, we recognize that distinctions are sometimes made between African Americans and Black women, that not all underrepresented minority women are Black, and that many papers on STEM include all women. However, the intersectionality of being both female and Black/African American means that studies on just women and STEM will still have some bearing on the Black female experience, along with any papers on underrepresented minority and STEM. In addition, Black women are more likely than their White counterparts to face negative consequences due to lower socioeconomic status. Although recent programs brought the U.S. Black poverty rate in 2019 to its lowest since poverty rates were first determined by the U.S. Census Bureau in 1959, African

Americans still faced the highest poverty rate of any demographic group, at 18.8% (Creamer, 2020).

Synthesizing Black Women in STEM

We acknowledge the interplay between race, gender, and ethnicity in the underrepresentation of Black women in STEM. Taken separately, the bodies of education research focused on the experiences of Black students and female students in STEM fields often render Black women and girls "hidden figures" in that they have not sufficiently addressed their simultaneous racialized and gendered experiences in educational contexts (Ireland et al., 2018; McGee & Bentley, 2017). In a similar vein, Collins (2015) problematizes the notion of underrepresentation of Black female students in STEM, stating that:

> We find that the current discourse on intersectionality is limited in that it does not attend to key psychological processes associated with identity, system racism, and the intersectional experience in STEM education.

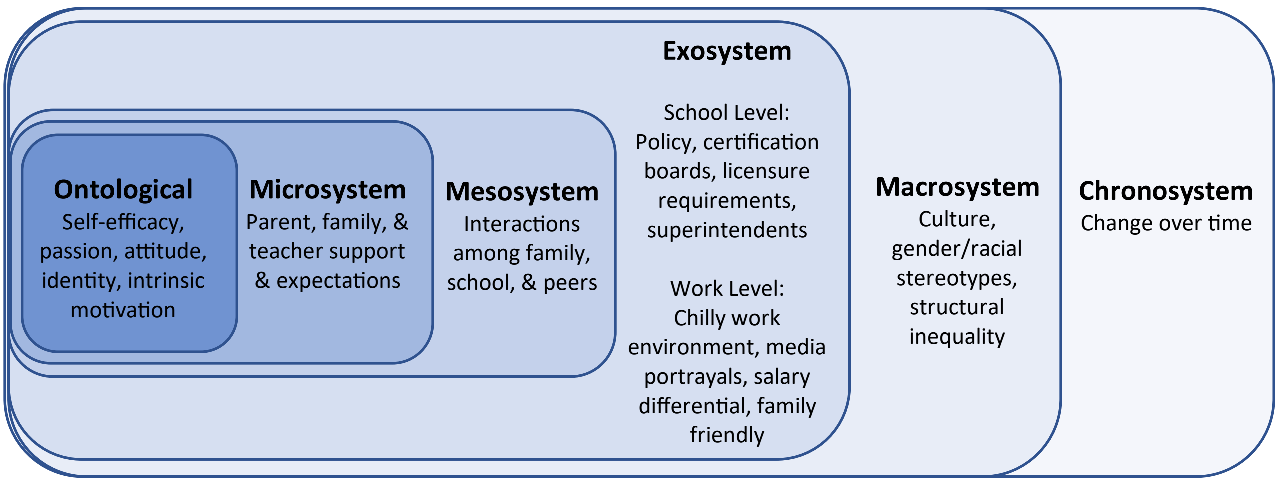
We take a theoretical and methodological approach to examining intersectionality in STEM education using the ecologic model to provide a fresh conceptualization in capturing the misrepresentation of Black women in STEM. Hence, this conceptual paper begins with synthesizing the main current psychological literature on the underrepresentation of Black women and highlights design limitations in the current research focused on understanding the causes of underrepresentation of Black women in STEM fields.

The underrepresentation of Black women is viewed as an ecological phenomenon, referencing the biological "branch of science concerned with the interrelationships of organisms and their environments" (Merriam-Webster, n.d., para. 1). An ecological model has the capacity to address complex, intractable, real-world issues, including disparities and inequalities (Hawe et al., 2009). As such, research on this topic requires this more holistic approach to identify risk and protective factors across the ecological settings that would contribute to creating meaningful interventions and policy. Therefore, as Crenshaw (2016) argued articulation of intersectionality in understanding certain identities makes it vulnerable to discrimination and exclusion. In line with McGee and Bentley, (2017) our understanding of intersectionality as it relates to identity is not simply as a matter of group membership but as the psychological meaning of membership in oppressed groups. These considerations include the personal, interpersonal, and structural implications, associated with group membership intersections are examined through an ecological prism.

Bronfenbrenner espoused a multitude of dynamic interactions between ecologies, or environmental layers, that exert a bidirectional developmental influence on an organism or individual (Mcleod, 2023). Briefly, Bronfenbrenner's (1994) system includes the subject's individual (ontogenic) variables and five outside systems: the micro-, meso-, exo-, macro-, and chronosystems. Proximal processes that occur in the microsystem involve interactions between an individual and the immediate environment, including family, school, and work settings. The mesosystem represents interconnections among these settings, such as the collaborative relationship between parents and teachers that will affect a student's motivational aspiration to pursue STEM courses in school. Both the micro- and mesosystems are nested within an exosystem that can directly impact micro- or mesosystems without the student's direct participation or involvement in the environmental layer (e.g., a school superintendent). The macrosystem captures the influence of broader cultural blueprints such as the belief systems, worldviews, or cultural identities, that envelop the other system ecologies. Finally, the chronosystem captures the influence of time and transition on development, such as the impact of changing schools, or episodes of social crisis, such as impact of the Coronavirus 2019 (COVID-19) pandemic on the transition to virtual learning. Bronfenbrenner's (1994) ecological model offers an approach that emphasizes the dynamic interactions between systems as well as within them, providing the necessary framework to conceptualize, analyze, and suggest solutions to the problem of Black women's underrepresentation in STEM fields. Figure 1 illustrates the model.

Figure 1

Ecological Model to Conceptualize Black Women's Underrepresentation in Science, Technology, Engineering, and Math Fields



Emerging Framework: Methods

The following section is a literature synthesis with findings classified according to the systems of Bronfenbrenner's (1977, 1994) ecological model. Applying this model exemplifies the analogy of the bicycle, where all individual parts must work together in concert to achieve progress. Our contention is that the vast majority of studies have been undertaken on certain aspects of the ontogenic, microsystem, and macrosystem aspects of Bronfenbrenner's (1977) ecology, at the expense of the mesosystem, exosystem, and (to a lesser extent) the chronosystem. Kanny et al. (2014), for example, looked at 324 full-text articles about STEM research dating back to the 1970s and found relative consistency over time in the subjects of the articles. They divided the articles into five topics: individual background characteristics (such as gender); structural barriers in K-12 education; psychological factors, values, and preferences; family influences and expectations; and perceptions of the STEM fields. Three of these (individual characteristics, psychological factors, and perceptions of the STEM fields) for the most part fall under ontogenic. Structural barriers in K-12 education clearly involve looking at the microsystem and macrosystem. Family influences would fit into the microsystem as well.

In a similar study, Avolio et al. (2020) analyzed 470 journal articles published between 1985 and 2018 on factors that contribute to the underrepresentation of women in science careers worldwide and came up with a classification system similar to Kanny et al.'s (2014). Avolio et al. also found five topics: individual, family, social, educational, and labor-economic. Once again, although there is not a clear-cut one-to-one match with Bronfenbrenner's (1994) ecology, individual fits precisely with the ontogenic, family and educational can slide into microsystem, and social and labor-economic fall for the most part under macrosystem. Avolio et al. concluded that the quantitative studies they analyzed "focus primarily on correlating a specific variable or factor with the participation of women [in science] in a specific stage of their life cycle" (p. 787), with few studies taking a long-term (chronosystems) approach. The specific variable most papers delved into, according to Avolio et al., was self-efficacy, and this focus was undertaken without much thought given to contextual factors, such as family support or financial difficulties. Studies tackling more than one variable and taking a broader historical view were lacking.

Basham et al. (2010) used Bronfrenbrenner's (1977, 1994) ecological model to describe the complex levels and systems within STEM education, studying approaches in Ohio schools as part of a STEM For All initiative. The article was focused on including students with disabilities rather than diverse students in general. Even when an ecological approach to African American students' experiences in STEM education has been undertaken, such as that by Stipanovic and Woo (2017), most of the emphasis has been on the ontogenic, covering for the most part variables within an individual, such as passion, career interests, intrinsic motivation, and goals. Stipanovic and Woo briefly mentioned students working with counselors (a microsystem approach) and parents coming to the school to meet with the counselors (a mesosystem approach). However, references to the exosystem or chronosystem were noticeably missing, which is a gap we aim to close.

Conceptualization of Black Women in STEM Through Ecological Theory

Ontogenic

The subject's individual variables include such items as intrinsic motivation, passion, career interests, and goals. This is also called the ontogenic level (Stipanovic & Woo, 2017). The idea that boys have some built-in advantage in STEM when compared to girls has very little support. However, Ceci et al. (2009) noted in the United States the almost 2:1 "persistent sex differences in spatial reasoning and mathematical ability at the right tail" (p. 35), the highest scoring subjects on SAT-M and GRE-Q. Ceci et al. contended the results might reflect biological factors or, more likely, sociocultural factors, particularly since (a) other countries showed no difference at the right tail or differences favoring women and (b) right tail differences in the United States have lessened over time.

For the most part, according to Else-Quest et al. (2013), girls do just as well as boys in science and math. Yet, according to the authors, male adolescents reported greater math self-concept and expectations of success than girls, whereas girls reported more value than boys in learning science. Explanations for this disparity rest somewhere other than innate potential and will be discussed further in the macrosystem section.

In a review of gender disparities in STEM disciplines, Eddy and Brownell (2016) discovered that in studies controlling for student ability (such as prior high school or college course grades), men seemed to outperform women. Studies that did not control for ability showed no achievement gap or showed a gap favoring women (Eddy & Brownell, 2016). Furthermore, the authors reported no difference in academic performance between women who persist and those who drop out of STEM courses, thereby concluding that achievement does not explain persistence. Masten and Coatsworth (1998) reported after observing successful children, they typically attributed their successes to hard work and their failures to lack of effort. This relates to Dweck's (2008) theory that mindset about intellectual abilities impacts achievement. Those who believe they can learn a skill will work harder toward mastery whereas those who believe they are inherently bad at math will not make the effort (Dweck, 2008).

Reviewing over 30 years of research, Wang and Degol (2017) found that while boys outnumbered girls by 4:1 and 2:1 in the top 0.01% of math tests of the SAT and ACT, respectively, gender differences in overall math scores have become negligible. Wang and Degol explained the fact that women still represent below 25% in many STEM fields and noted, "individuals . . . with higher math skills relative to verbal skills are more likely to pursue STEM careers, while individuals with comparably high math and verbal ability are more likely to pursue non-STEM careers" (pp 121–122). Because girls are more likely to possess both high math and verbal skills and boys are more likely to exhibit higher math than verbal ability, fewer girls go into STEM. Ceci et al. (2009) agreed that a "powerful explanatory factor" (p. 251) for the underrepresentation of women in math-intensive fields is that mathematics-capable women disproportionately choose non-mathematics fields.

In addition, according to Wang and Degol (2017), women are simply "wired" (p. 124) to go into fields that help people, even within STEM, getting more degrees in biomedical and environmental engineering than mechanical or electrical engineering, for example. Dicke et al. (2019) agreed that women tend to desire careers that help others, whereas men want to work with tools and machines while making lots of money. One simple method to enhance the aspiration and participation of more women into traditional STEM fields is "to better contextualize the human applications of these fields" (Dicke et al., 2019, p. 11). Wang and Degol agreed that adding more storytelling to STEM learning, relating real-world examples in STEM courses, and explaining exactly what engineers do can help attract women to STEM. Furthermore, McGee and Bentley (2017) described the study of career aspirations of high-achieving Black and Latinx undergraduate STEM majors using an equity ethics lens. Following interviewing 38 Black and Latinx STEM students, they found that students' desire to help others indicates a need to revisit the emphasis on financial success in STEM fields. They also highlighted the need for STEM education programs that present broader STEM career possibilities, including careers that integrate social justice, empathy, and equity matters.

Ceci and Williams (2011) and Wang and Degol (2017) claimed historical sexism no longer is a valid reason to explain the gender gap in sciences. Ceci and Williams discussed the "biological realities" (p. 3157) that cause women to make decisions based on fertility/lifestyle choices. However, Rutherford (2020) disagreed and claimed that efforts to understand why women do not "fit" into science are wasted (p. 27). Women's preferences, Rutherford countered, are shaped by the ways "gendering" actually makes "'hard' science *appear to be* abstract and non-people oriented" (italics in original, pp. 27–28). Because Rutherford's argument slips into the chronosystem factor, it will be more closely examined in that portion of the paper. However, it is fair to say, as Alawi and Murbarak (2019) did, that childbirth/maternity barriers can play a role in women's choices. Obviously, questions about support for mothers—and fathers—in terms of childcare, child tax credits, and paternity leave are best left for coverage in the exosystem section. However, given the sensitive nature of discussion about women's health care in 21st century America, it is clear the country is not yet in a post-gender epoch, and the biological realities of child bearing and rearing deserve as much attention in science careers as any other.

Microsystem

According to Bronfenbrenner (1977), the microsystem represents "the complex of relations between the developing person and environment in an immediate setting containing that person" (p. 514), such as home, school, or workplace. Microsystem refers to the environment where a student interacts with educators, noninstructional staff, peers, and administrators.

Makarova et al. (2019) viewed teacher training as critical for reducing gender bias in schools. Just having better teachers, they argued, mediates the effects of gender inequality. Cong et al. (2021) confirmed that unhealthy interactions with instructors can cause women to prioritize liberal arts. According to Hand et al. (2017),

> High school teachers tend to underestimate girls' mathematical abilities while overestimating boys' mathematical abilities, and science professors at universities throughout the country have been shown to favor male applicants for a research assistant position in the sciences, even when identical applications from fictitious men or women were presented. (p. 930)

Kuchynka et al. (2022) and Masten and Coatsworth (1998) also listed teacher training as important for creating gender-affirming education systems. According to these authors, successful schools have a clear mission that fosters cooperative classrooms, imparts knowledge about the history of gender inequality, insists on high-quality instruction, carefully monitors student progress, and creates mentorship programs. Because the atmosphere in STEM fields can be unwelcoming for underrepresented minoritized people and women (Blackwell et al., 2009), educators need to create networks for women once they enter STEM programs to reduce sexism and improve academic climates (Settles et al., 2016). Teacher training issues will be picked up again under the exosystem section.

Public education funding sources can limit the offerings at some schools, both rural and urban (Zhang & Barnett, 2015). One way to support schools with fewer resources is to create a system of dual credit classes at local community colleges (Stipanovic & Woo, 2017). Although an obvious win for students and community colleges looking for higher enrollments, those who create postsecondary opportunities for high schoolers need to keep in mind that pulling the best students from high schools may exacerbate problems of peer role models at those high schools. In addition, problems regarding restrictions of sharing information about college students with parents need to be addressed up front, and students in dual credit classes need to be made aware that failing the college class also may interfere with their high school diploma.

Further, parents play a pivotal role in their children's education. Warm, firm parenting with high expectations regarding education is associated with academic success (Masten & Coatsworth, 1998). However, parents with limited knowledge of STEM can negatively impact their daughters' decisions about potential STEM careers (Alwai & Al Murbarak, 2019; Zhang & Barnett, 2015). Wang and Degol (2017) found that parents' math ability beliefs about their children were associated with their children's beliefs. Along similar lines, parents' endorsement of gender stereotypes can impact their children's self-perceptions (Schmader et al., 2004). Gender stereotypes dismissing women's math ability negatively impact a woman's view of her potential: "Women majoring in male-dominated fields who believe that status differences between men and women in society are legitimate are more likely to endorse gender stereotypes about women's math ability" (Schmader et al., 2004, p. 841), lowering their desire to remain in the field of math. In somewhat contradictory findings, Ceci et al. (2009) reported that parental and teacher encouragement in math were "downplayed as a primary causal factor in women's current underrepresentation in math-intensive fields, because the mechanisms by which they act is unclear" (p. 13).

The microsystem of peers, home, school, or workplace affects an individual's choices. Mixing a bit of microsystem and macrosystem, Mullet et al. (2017) concluded that women with a high interest in STEM who receive encouragement from their families and peers, who are not discouraged by the academic institutions they attend, and who are not distracted by cultural masculinist norms can be successful.

Mesosystem

According to Bronfenbrenner (1977), the mesosystem represents "the interrelations among major settings containing the developing person at a particular point in his or her life. Thus, for an American 12-year-old, the mesosystem typically encompasses interactions among family, school, and peer group" (p. 515). The mesosystem covers the interaction of two or more microsystems, such as parents and school staff. Parental involvement in a child's school life is key to improving academic success (Masten & Coatsworth, 1998). Proof of such a claim comes from Mau et al. (2020), who found after measuring approximately 600 Taiwanese and 600 American students that gender differences favoring male students in STEM self-efficacy were greater in Taiwan, perhaps because Taiwanese male students reported more parental involvement in their education than Taiwanese female students, whereas there was no gender difference in parental involvement for American students. Interviewing African American students about their STEM experiences, Stipanovic and Woo (2017) found that, simply by coming to the school and meeting with counselors, parents could have a positive impact on their children's interest in STEM.

Exosystem

According to Bronfenbrenner (1977):

> An exosystem is an extension of the mesosystem embracing other specific social structures, both formal and informal, that do not themselves contain the developing person but impinge upon or encompass the immediate settings in which that person is found, and thereby influence, delimit, or even determine what goes on there. (p. 515)

Exosystem refers to social structures that impact students, such as policy issues, teacher education programs, and certification boards.

Many of the macrosystem debates over large policy issues play out in the exosystem, which includes any setting in which the child is not directly involved such as education programs and certification boards. Studies in education using the ecological model have not placed much emphasis on the exosystem, but it can have great impact. For example, the debate over teacher licensing exams is getting some attention. On one side are those who believe that licensing exams and licensure requirements are being systematically lowered but should be kept at a stringent level because teachers who know their subject matter, particularly math, are better teachers. On the other side are those who believe that licensure tests keep out diverse teachers, the kind that studies show are integral to a good education, particularly for underrepresented minority (Barrios et al., 2023). Obviously more research should be able to pinpoint a sweet spot on licensure exams that ensures subject matter knowledge but does not impede diversity.

Superintendents also play a vital role in creating STEM-focused school districts. In particular, superintendents need to work with principals to improve parental STEM awareness, according to Watson et al. (2020). The authors stressed that parents need to be incentivized to attend school programs that promote STEM careers, need more information about the importance of STEM, and need to be invited to sit on district STEM councils (Watson et al., 2020). In addition, STEM employers can be invited to schools and made available to both parents and students. Some companies have STEM advocates. Superintendents must play a central role in a national effort “to create a continuum of learning” about STEM that is clear for instructors and students at all levels (Steward, 2013, p. 45). To accomplish this, certification programs for superintendents need to pay more than just lip service to STEM development.

Mass media also is an integral part of the exosystem. Mass media-inspired misinformation and disinformation may have a negative effect on career choice. However, little research has been undertaken on the impact of knowledge gaps created by the a media landscape filled with pundits willing to spread antivaccine information targeting African Americans (Stone, 2021), for example. What can happen to a child’s desire to be a scientist to help people when science is belittled by politicians and other influential talking heads as a way to cause harm?

The power of media to change attitudes has been shown by Cheryan et al. (2013). The authors found that undergraduate women at two U.S. West Coast universities who read fabricated articles that promoted women in computer science were more interested in a career in computer science than those who did not. Other efforts to inspire underrepresented minority women to pursue STEM careers include portrayals of women and men in textbooks to avoid gender bias (Cong et al., 2021). Makarova et al. (2019) agreed that changing how gender roles are depicted in textbooks can positively impact the desire of both men and women to go into math-intensive fields.

In addition, books themselves can be part of the educational problem due to the mismatch between students’ reading skills and text-based curricula as well as students’ deficits in background knowledge that can interfere with learning new concepts in any fields, including STEM (Basham et al., 2010). Supporting teachers so they can provide explicit vocabulary instruction, anchored instruction (where students use prior knowledge to solve reality-based scenarios), and content-area reading strategies have been shown to improve student outcomes (Basham et al., 2010).

Getting Black female students into STEM tracks is just one part of the job. Keeping them in STEM careers is another. One way to make sure women persist in STEM fields is to pay women in STEM the same salary as men (Cong et al., 2021). Wang and Degol (2017) also stressed the importance of accommodating women in the workplace. In-house daycare, breast-pumping stations, and family leave may need to be championed in the legislative arena, part of the exosystem.

Macrosystem

The macrosystem refers to societal blueprint for a particular culture, worldview, and broader beliefs system (Bronfenbrenner, 1988). According to Bronfenbrenner (1977), macrosystem "refers to the overarching institutional patterns of the culture or subculture, such as the economic, social, educational, legal, and political systems, of which micro-, meso-, and exosystems are the concrete manifestations" (p. 515). Macrosystem represents cultural beliefs that may hinder underrepresented minority participation in STEM fields.

The ecology model's macrosystem, which deals with social norms and culture, appears to have garnered the most attention among STEM researchers. One reason for the focus, according to Xie et al. (2015), is that whereas socioeconomic status predicts attainment in general education, social-psychological factors are even more important for STEM achievement. Two of the most mentioned aspects of the macrosystem are stereotypes and gender bias, which are related. Blackstone (2003) defined gender stereotypes as “oversimplified understandings of males and females and the differences between them” (p. 337). The term “gender roles,” according to Mim (2019), “refers to the different stereotypical behaviors and traits expected from men and women by society” (p. 61). These stereotypes or gender roles can arise from many sources, including parents, peers, and teachers. Hand et al. (2017) found that both teachers and students attributed more masculine characteristics to the sciences and feminine characteristics to the humanities. Schmader et al. (2004) reported that parents’ endorsement of gender stereotypes can impact their children’s self-perceptions.

In turn, women who believe that status differences between the sexes are “legitimate, stable, and impermeable” are more likely to endorse gender stereotypes in math-related fields and will perform less well (Schmader et al., 2004, p. 841). In addition, an orientation toward social dominance theory, the belief that one group must dominate, can lead to the kind of political conservatism, sexism, racism, and belief in a meritocracy that endorses gender stereotypes (Schmader et al., 2004). Eddy and Brownell (2015), Alawi and Al Mubarak (2019), and other researchers stressed that stereotypes and gendered socialization can negatively affect women’s interest in STEM, particularly if they “base their perceptions about appropriate gender roles upon gender stereotypes” (Blackstone, 2003, p. 337). For women 16–18 years of age, their traditional gender role beliefs “significantly predicted” the likelihood they would be in a STEM field at the age of 42 (Dicke et al., 2019, p. 1). Stereotypical traits of scientists as objective, rational, and single-minded “are more consistent with typically male gender-normative traits” and can lead to identity interference in women, which can cause “negative psychological well-being, physical health problems, and negative workplace outcomes” (Settles et al., 2016, pp. 489–490). Gender stereotypes work not only by convincing women they do not want to enter a field because of their expectations about the field but also by leading women to underestimate their ability in STEM fields (Cong et al., 2021). Studies by Jugović (2017) showed a clear need to deconstruct stereotypes to increase diverse participation in subjects like physics.

One of the gender stereotypes associated with women is the need for a sense of belonging. Lewis et al. (2017) defined a sense of belonging as the "subjective feeling of fitting in and being included as a valued and legitimate member in a particular setting" (p. 421). Cheryan et al. (2017) ascribed part of the underrepresentation of women in some STEM fields to masculine cultures "that signal a lower sense of belonging to women than men" (p. 1). Eddy and Brownell (2016) also explained the gender gap in STEM occupations by men having more of a sense of belonging within STEM fields. Lewis et al. concluded in a study of STEM gender differences in 3,000 higher education participants that a sense of belonging explained persistence intentions and actual persistence in STEM coursework for women more reliably than self-efficacy or achievement. Cheryan et al. (2013) blamed stereotypes for compromising "women's sense of belonging" (p. 61) and therefore discouraging them from pursuing jobs in STEM. In fact, the gender disparity in the pursuit of STEM careers disappears "when women perceived high opportunity for communion" (improving the lives of others) in such careers (Stout et al., 2016, p. 490).

Several approaches can be taken to ameliorate the negative impact of the stereotype of a scientist as an unattractive, pale man in glasses wearing a lab coat, lacking interpersonal skills, and working alone (Cheryan et al., 2013). Referring specifically to computer science, engineering, and physics, Cheryan et al. (2017) championed "providing students with early experiences that signal equally to both girls and boys that they belong and can succeed in these fields" (p. 1). Simply by taking 5- to 12-year-olds to a science museum helped reduce gender stereotyping after one growth-mindset intervention in a study conducted by Law et al. (2021).

Increasing the number of Black STEM role models, in theory, is one path toward helping decrease the STEM familiarity gap within ethnic groups and those of low socioeconomic status (Settles et al., 2016). A small majority of Black adults, for instance, believe that young Black people would be much more likely to pursue a tertiary STEM degree if there were more examples of high achievers in those areas, similar to high-achieving Black athletes, musicians, lawyers, and clergy (Funk, 2022). Several researchers have reported that providing more female role models could help recruitment of women into STEM fields (e.g., Wang & Degol, 2017). By measuring how quickly subjects categorized words related to math and English with positive or negative words, Stout et al. (2011) concluded that "exposure to female STEM experts promoted positive implicit attitudes and stronger implicit identification with STEM, . . . greater self-efficacy in STEM, . . . and more effort on STEM tests" (p. 255) among female subjects. Even putting posters of Black scientists on classroom walls can be beneficial (Brown et al., 2017).

A couple of problems arise when looking at the obvious benefits of Black female role models in STEM authority positions in academic institutions and businesses. First, developing more Black women STEM professionals and getting them just a fraction of the attention that athletes and entertainers receive is at best a long-term goal. Second, some macro- and chronosystem issues need to be addressed before Black female STEM role models can be used successfully to influence others. Analyzing workshops of predominately female STEM professionals from 25 different cultural backgrounds, McKinnon and O'Connell (2020) found that "women who publicly communicate their work are likely to be stereotyped as 'bitchy', 'bossy', and 'emotional'—often by their own gender" (p. 1). Although the subjects of their study were not students, just dropping an underrepresented minority female scientist into a current classroom may not have the desired effect. In fact, Hawkins et al. (2019) discovered by using digital learning games that younger students (ages 9–10) were more motivated by high-masculine and low-feminine avatars in STEM-based computer learning tools. Older students, conversely, were motivated more by the scientists' sex and not the level of gender expression. Based on the female subjects' game scores, hypersexualized game characters have been found to reduce female players' motivation for STEM-based classes and careers.

One of the more interesting macrosystem findings among STEM researchers has to do with the political nature of countries in relation to their gender gap in STEM. Research has indicated that more egalitarian countries show less of an achievement gap in mathematics between men and women, but women's interest in pursuing STEM careers in those countries still remains low (Hand et al., 2017). Called the gender paradox, the STEM gender gap actually increases as the country grows more gender-egalitarian (Mann & DiPrete, 2016). Among high-performing girls, however, according to Mann and DiPrete (2016), the STEM gap decreases with the growth of the national performance environment even as the overall gender gap in STEM grows. The reason for this, according to the authors, is that before forming STEM orientations, girls hold themselves to a higher performance standard, and this standards gap grows with the strength of a country's performance environment.

For example, Finland excels in gender equality, its adolescent girls outperform boys in science literacy, and it ranks second in European education performance (Stoet & Geary, 2018). With these high levels of educational performance and overall gender equality, Finland should be "poised to close the STEM gender gap. Yet, paradoxically, Finland has one of the world's largest gender gaps in college degrees in STEM fields, and Norway and Sweden, also leading in gender-equality rankings, are not far behind" (Stoet & Geary, 2018, p. 581). The authors suggested that gender-equal countries offer greater opportunities to pursue individual interests.

One posited way to fix gender gaps in STEM fields is to pass laws requiring students to take advanced math courses. One German educational reform did just that. In a study of approximately 4,700 students, Hübner et al. (2017) found that whereas gender differences in math achievement were smaller after the reform, differences in math self-concept were actually larger. Furthermore, the law had no impact on choices students made in their fields of study. Reducing options, the authors concluded, does not necessarily increase gender equality in STEM career choice.

Chronosystem

The chronosystem represents change or consistency over time not only in the characteristics of the person but also their surrounding setting and environment (Bronfenbrenner, 1994). Chronosystem refers to changes over time, including the aging of the student and the changes over time that impact a teacher or administrator (Ruppar et al., 2016).

Several studies from the 1970s high school math classes showed that teachers favored male students while "females, relatively speaking, were treated with benign neglect," even when a majority of the instructors were women (Ceci et al., 2009, p. 12). Given the focus on the women's movement, the number of female students interested in science at the secondary level has increased since the 1990s, but unfortunately that has not translated to more women pursuing STEM education at the tertiary level or STEM-related jobs. As sex differences erode in some areas, female stereotypes have changed more than male stereotypes. The change, according to Diekman and Eagley (2000), is primarily accounted for by "increasing ascription of masculine characteristics to women" (p. 1176). Looking at the same trends 14 years later, Kanny et al.

(2014) highlighted the "notable variation" in aspirational trends by gender and asked "whether extant explanations for women's continued underrepresentation in STEM have also evolved over time, and to what degree this evolution, or non-evolution, has been suitably addressed in scholarship on the gender gap in STEM" (p. 128).

Rutherford (2020) has taken a historical view to come at the gender gap from another angle. For example, computer programming was, in its origins, a feminized occupation, according to historian Nathan Ensmenger (2015, as cited in Rutherford, 2020). Nothing about computer programming made it unsuitable for women or "made it a necessarily solitary pursuit requiring eccentricity and genius. It was constructed that way" (Rutherford, 2020, p. 28). Consequently, rather than trying to figure out how to turn science pink, it would be best to figure out how it was turned blue in the first place. This kind of "attention to the gendering of science" can help dismantle stereotypes (Rutherford, 2020, p. 28).

Among several gems within chronosystem facts, a belief in the Protestant work ethic, which used to indicate a view that status differences between the sexes were legitimate, now seems to contradict this belief, instead implying that gender differences are not stable and can be overcome, if necessary, by hard work (Schmader et al., 2004). This fits with suggestions by researchers (e.g., Wang & Degol, 2017), and theorists (e.g., Dweck, 2008) that parents and teachers need to emphasize effort and hard work instead of talent.

Discussion

Economic, national security, and social justice issues all call for increasing the number of Black women in STEM careers. In the first decade of the 21st century, the percentage of undergraduates pursuing bachelor's degrees in physical science, engineering, and math remained stagnant, while the percentage of those studying computer science declined (Kanny et al., 2014).

Adding to the problem is the persistent underrepresentation of women in some STEM fields. Both these facts have led the U.S. federal government to identify increasing the numbers of students enrolled in STEM fields as an area of "national need" (Kanny et al., 2014, p. 127). While much effort has been expended to do just that, room for improvement remains. Taking an ecological model approach, which has been applied across disciplines, to search for the gaps in the research in the various systems is one way to approach potential avenues for new studies. As a broad, holistic theoretical framework, the ecological model will inform rigorous multidisciplinary research to identify the proximal and distal processes and the corresponding reciprocal interactions between them.

The angry debates over gender within the national political sphere cannot be ignored when examining ontological approaches to the gender gap in science. Women face some employment hardships that are different from those of men, such as childbearing. If science- and math-oriented businesses could create the most female-friendly working environments in the United States, it might improve recruiting. Whereas some researchers have gone so far as to suggest that prejudice is a historic, not current, cause of women's underrepresentation (Wang & Degol, 2017), few are naïve enough to believe that bias against women in academics and the workplace has been eliminated. However, perhaps it is time to worry about the impact of expensive and hard-to-find childcare, lack of breast pumping stations in the workplace, and other issues of particular interest to women.

Making sure that public schools are adequately funded to provide a high-quality science and math education is critical but perhaps out of the scope of this paper. However (at the risk of mixing the microsystem with the exosystem), reviewing teacher training and superintendent training programs, along with licensure requirements, to make sure they take into account the need to create schools that create students interested in STEM is worthy of further study. Community colleges and universities also should take measures through professional development to support teacher competency in teaching STEM disciplines.

The mesosystem, particularly the nexus of parents and schools, needs much more attention. Finding ways to engage parents to make school a part of their lives along with their children's is crucial. We do not need another study of the importance of parent participation, but rather more studies about practical strategies to accomplish that.

Regarding the macrosystem, more studies are needed on how to tackle politicized issues within the sciences, like climate change. Health care and its intersection with policy have a particular impact on women, and climate justice plays a critical role in the lives of underrepresented minority .

The area that might deserve much more attention given the political divide in the country is the role science skepticism might play in career choice. Students who have spent a couple of years under COVID-19 pandemic conditions are ripe subjects for many research projects, including the impact of debates over efficacy of vaccines. Indeed, just 29% of adults in the United States reported in 2022 that they have a great deal of confidence in medical scientists, as opposed to 40% just 2 years earlier, while the share of U.S. adults expressing a great deal of confidence in scientists to do what is best for the public dropped from 39% to 29% (Kennedy et al., 2022). How those numbers impact the decisions of students to study toward a science degree is important at the least and frightening at the worst.

Conclusion

Positive trends for women's participation in the workforce, according to Kanter (1977, as cited in Avolio & Chávez, 2023, p. 1), were "the most important silent revolution" in the 20th century, with women accounting for 46.3% of the world's current total workforce. However, women still lag behind in participation rates for specific fields, particularly in the sciences. One alarming fact is that as of 2022, women had won just 3.5% of Nobel Prizes in the sciences ("Nobel Prize Awards," 2022). Although the percentage of women Nobel Prize winners increased a little over 0.5% in the last decade (Avolio & Chávez, 2023), it is still a clear indication of wasted talent. Indeed, the United Nations Educational, Scientific and Cultural Organization (1999) stated that STEM gender equality is essential not only for social justice and ethical reasons but also for the achievement of the full potential of scientific communities.

It is worth noting that, at a national level, the U.S. is not producing and retaining "a sufficient number of STEM-related workers and researchers" (Kozan et al., 2017, p. 206) and lags behind many other countries in percentage of bachelor's degrees awarded in STEM fields (World Economic Forum, 2016). Young et al. (2017) argued, "Diversifying the STEM workforce is a national concern" (p. 174). Likewise, Alexander & Hermann, 2016) agreed, stating STEM employment is "essential for America's economic development and ability to compete internationally" (p. 308). However, if the number of Black women who entered STEM programs were retained in the STEM workforce, the shortage of STEM workers in the United States might be resolved (Joseph et al., 2023).

To be sure, existing programs to help underrepresented minorities have shown some success, while the relative gains have slowed since 2000 (Garrison, 2013), meaning there is still much room for improvement. Just 25% of all STEM jobs are occupied by women (Simon et al., 2017). Numbers for Black women are even more dismal. According to 2019 data from the National Center for Science and Engineering Statistics at the National Science Foundation (as cited in Allen-Handy et al., 2020), Black female college graduates earn just 4.5% of biological sciences, 2.2% of computer science, 2.5% of physical sciences, 2.1% of mathematics and statistics, and 1.0% of engineering degrees. Given these numbers, many scholars have claimed grave inequalities continue to exist across socioeconomic, gender, and race lines in STEM education (Allen-Handy et al., 2020).

Nevertheless, recognizing that women make up half of all U.S. workers but only 12% of apprentices, in 2021 the U.S. Department of Labor announced a Women in Apprenticeship and Nontraditional Occupations Technical Assistance Grant Program, which will fund grants to increase and retain women in occupations such as cybersecurity and health care. At the same time, the National Science Foundation planned to award grants to promote racial equality in science, technology, engineering, and math (STEM) education (Juszkiewicz, 2021). Focusing on STEM, especially for underrepresented students, is clear. Paving the path for more Black women to enter and succeed in STEM careers will generate multiple benefits both for those women and for the United States as a whole.

The current gender gap and sexual division of labor has been blamed on biology, capitalism, and household cost–benefit analysis (Avolio & Chávez, 2023). Studies of this gender and ethnicity gap fall into several different categories that mesh sometimes smoothly and sometimes less so with an ecological systems approach. For example, Avolio and Chávez (2023) divided the research on the STEM gender gap into four areas: biological, psychological, sociocultural, and epistemology of science. The biological and psychological fit with the ontological (or individual) section of the ecological systems, whereas the sociocultural and epistemology of science approaches fit into the macrosystem.

To best understand the causes of gender and ethnic differences in math-intensive STEM fields that hinders especially Black women and girls, investigators must realize that risks to development co-occur, accumulate over time, and are multifactorial (Masten, 2001). For that kind of integrative approach, Bronfenbrenner's (1977, 1994) ecological systems model is extremely useful. This model can be adapted to different disciplines, historical periods, cultures, and developmental levels (Ceci et al., 2009). Starting with biological sex in the center, researchers can study the interplay of various aspects of the systems within the rings (levels) and between the rings. In the traditional research model, behavior and development are investigated in one setting at a time without regard to possible interdependencies between settings. Instead of the traditional single-setting research approach, broader and more comprehensive research is needed from ecological, multi-nested approach to focus on Black women and girls STEM promotion resources, which increase the aspiration, recruitment, talent development, and retention of Black women and girls in the STEM pipeline.

In tackling the underlying problems of the underrepresentation of Black women and girls gap in STEM, taking an ecological approach can be seen as an umbrella concept to help develop conditions and strategies with focused solutions to those problems. National concerns about student achievement, and in particular those of Black women and girls on international performance assessments, should drive policy at the national, state, and local levels. These macrosystem concerns can lead to a desire to build STEM capacity through teacher training for Black women and girls, which is part of the exosystem. Also, preparation of Black women and girls for STEM should be analyzed through the ecological systems model.

Just as a bicycle only moves forward when all interconnected parts are functioning, it is essential to go beyond the traditional deficit model and adopt strengths-based models that boost available and consider new resources from multi-pronged settings (e.g., homeschooling, community-based cultural approaches) that benefit and promote successes for Black women and girls in the STEM talent pipeline. Implementation of the ecology construct in practice with Black women and girls in STEM, shifts "blaming the victim" orientations to a solution approach that emphasizes the importance of identifying a kit of resources that will boost the success of Black women and girls in STEM. An extension of this model could include Antonovsky's (1996) autogenic research orientation, which shifts attention from risk factors toward resources that can be utilized across settings to contribute to success and resiliency. This refocusing of the question allows a forward emphasis on shared responsibility, identifying assets and resources rather than risk factors, with the ultimate goal of introducing more policies for improving and promoting the successful presence of Black women in the STEM economy. STEM competency building is not a dualistic proposition, but instead occurs as a progression on a continuum, where cross-system resources can be used to promote the successful presence of Black women in STEM. Bias, stereotypes, and systematic structures that are associated with intersectionality contribute to Black women and girls not pursuing STEM careers. A review of the literature suggests that the structures needed in the current educational systems for Black women and girls to be successful in STEM are absent and or nonexistent. Present structures and systems have adverse influences that often overlook racist and sexist behavior which is the definitive principle of intersectionality (Spark, 2017) that explains the underrepresentation of Black women and girls in STEM fields and calls to bridge the gap of underrepresentation of Black women in STEM fields while enhancing access, participation and success through eco-system programs.

References

Adams, T., Robinson, D., Covington, A. & Talley-Matthews, S. (2017). Fueling the STEMM pipeline: How historically Black colleges and universities improve the presence of

African American scholars in STEMM. *Journal of Urban Learning, Teaching, and Research, 13*, 9–25.

Alawi, W. S. S., & Al Mubarak, M. M. S. (2019). Gender gap in science, technology, engineering and mathematics: Barriers and solutions. *International Journal of Economics and Financial Issues, 9*(6), 225–231. https://doi.org/10.32479/ijefi.8908

Allen-Handy, A., Ifill, V., Schaar, R. Y., Rogers, M., & Woodard, M. (2020). Black Girls STEAMING through Dance: Inspiring STEM literacies, STEAM identities, and positive self-concept. In K. Thomas & D. Huffman (Eds.), *Challenges and opportunities for transforming from STEM to STEAM education.* IGI Global. https://doi.org/10.4018/978-1-7998-2517-3.ch008

Alexander, Q. R., & Hermann, M. A. (2016). African-American women's experiences in graduate science, technology, engineering, and mathematics education at a predominantly White university: A qualitative investigation. *Journal of Diversity in Higher Education, 9*(4), 207–322. https://doi.org/10.1037/a0039705

Antonovsky, A. (1996). The salutogenic model as theory to guide health promotion. *Health Promotion International, 11*(1), 11–18. https://doi.org/10.1093/heapro/11.1.11

Avolio, B., & Chávez, J. (2023). Professional development of women in STEM careers: Evidence from a Latin American country. *Global Business Review*. https://doi.org/10.1177/09721509221141197

Avolio, B., Chávez, J., & Vílchez-Román, C. (2020). Factors that contribute to the underrepresentation of women in science careers worldwide: A literature review. *Social Psychology of Education, 23*, 773–794. https://doi.org/10.1007/s11218-020-09558-y

Barrios, H., De La Cruz Lopez, D. L., Maguire, C., & Utt-Schumacher, J. (2023, February 25). Counterpoint: Teacher licensure tests fail. Diversity succeeds. *Star Tribune* (Minneapolis), p. A13. https://www.startribune.com/counterpoint-teacher-licensure-tests-fail-diversity-succeeds/600254466/

Basham, J. D., Israel, M., & Maynard, K. (2010). An ecological model of STEM education: Operationalizing STEM for all. *Journal of Special Education Technology, 25*(3), 9–19. https://doi.org/10.1177/016264341002500303

Blackstone, A. M. (2003). Gender roles and society. In J. R. Miller, R. M. Lerner, & L. B. Schiamberg (Eds.), *Human ecology: An encyclopedia of children, families, communities, and environments* (pp. 335–338). ABC-CLIO.

Blackwell, L. V., Snyder, L. A., & Mavriplis, C. (2009). Diverse faculty in STEM fields: Attitudes, performance, and fair treatment. *Journal of Diversity in Higher Education, 2*(4), 195–205. https://doi.org/10.1037/a0016974

Brahm, J. (2021, January 31). STEM education should be a national security priority. *Space Force Journal.* https://spaceforcejournal.org/stem-education-should-be-a-national-security-priority/

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513–531. https://doi.org/10.1037/0003-066X.32.7.513

Bronfenbrenner, U. (1988). Interacting systems in human development: Research paradigms, present and future. In N. Bulger, A. Caspi, G. Downey, & M. Moorehouse (Eds.), *Persons in context: Developmental processes* (pp. 25–49). Cambridge University Press.

Bronfenbrenner, U. (1994). Ecological models of human development. In *International encyclopedia of education* (2nd ed., Vol. 3). Elsevier.

Brown, B. A., Mangram, C., Sun, K., Cross, K., & Raab, E. (2017). Representing racial identity: Identity, race, the construction of the African American STEM students. *Urban Education, 52*(2), 170–206. https://doi.org/10.1177/0042085916661385

Ceci, S. J., & Williams, W. M. (2011). Understanding current causes of women's underrepresentation in science. *Psychological and Cognitive Sciences, 108*(8), 3157–3162. https://doi.org/10.1073/pnas.1014871108

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's under-representation in science: Sociocultural and biological considerations. *Psychological Bulletin, 135*, 218–261. https://doi.org/10.1037/a0014412

Charleston, L.J., George, L., & Jackson, F.L. (2014). Navigating Underrepresented STEM Spaces: Experiences of Black Women in U.S. Computing Science Higher Education Programs Who Actualize Success, *Journal of Diversity in Higher Education 7*(3), 166-167.

Cheryan, S., Plaut, V. C., Handron, C., & Hudson, L. (2013). The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women. *Sex Roles, 69*, 58–71. https://doi.org/10.1007/s11199-013-0296-x

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143*(1), 1–35. https://doi.org/10.1037/bul0000052

Cho, S., Crenshaw, K. W., & McCall, L. (2013). Toward a field of intersectionality studies: Theory, applications, and praxis. *Signs*, *38*, 785–810. doi:10.1086/669608

Coleman, N. (2021). *Identifying structural changes made by district leadership to increase equity in STEM for Black girls* (Doctoral dissertation, University of Illinois Urbana-Champaign). https://www.ideals.illinois.edu/items/118276

Collins, P. H. (2015). Intersectionality's definitional dilemmas. *Annual Review of Sociology*, *41*, 1–20. doi:10.1146/annurev-soc-073014-112142

Collins, P. H., & Bilge, S. (2016). *Intersectionality*. Malden, MA: Polity Press.

Cong, W., Ding, J., Gu, J., Jia, R., & Zeng, J. (2021). The influence of gender role on gender segregation of STEM majors in Chinese universities. *Proceedings of the 2021 5th International Seminar on Education, Management and Social Sciences* (pp. 962–967). Atlantis Press. https://doi.org/10.2991/assehr.k.210806.183

Creamer, J. (2020, September 15). *Poverty rates for Blacks and Hispanics reached historic lows in 2019: Inequalities persist despite decline in poverty for all major race and Hispanic origin groups.* U.S. Census Bureau. https://www.census.gov/library/stories/2020/09/poverty-rates-for-blacks-and-hispanics-reached-historic-lows-in-2019.html

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum*, *1989*(1), Article 8. Retrieved from http://chicagounbound.uchicago. edu/uclf/vol1989/iss1/8

Crenshaw, K. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, *43*, 1241–1299. doi:10.2307/1229039

Crenshaw, K. (2016, March). *Kimberlé Crenshaw: WOW 2016 keynote. On intersectionality* [Video file]. Retrieved from https://www.southbankcentre.co.uk/blog/kimberl%C3%A9-crenshaw-wow-2016-keynote

Dicke, A., Safavian, N., & Eccles, J. S. (2019). Traditional gender role beliefs and career attainment in STEM: A gendered story? *Frontiers in Psychology, 10*, Article 1053. https://doi.org/10.3389/fpsyg.2019.01053

Diekman, A. B., & Eagly, A. H. (2000). Stereotypes as dynamic constructs: Women and men of the past, present, and future. *Personality and Social Psychology Bulletin, 26*(10), 1171–1188. https://doi.org/10.1177/0146167200262001

Dweck, C. S. (2008). *Mindsets and math/science achievement.* Carnegie Corporation of New York. http://www.growthmindsetmaths.com/uploads/2/3/7/7/23776169/mindset_and_math_science_achievement_-_nov_2013.pdf

Eddy, S. L., & Brownell, S. E. (2016). Beneath the numbers: A review of gender disparities in undergraduate education across science, technology, engineering, and math disciplines. *Physical Review Physics Education Research, 12,* Article 020106. https://doi.org/10.1103/physRevPhysEducRes.12.020106

Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement at the intersection of gender and ethnicity. *Psychology of Women Quarterly, 37*(3), 293–309. https://doi.org/10.1177/03616843134480694

Fuller, J. A., Luckey, S., Odean, R., & Lang, S. N. (2021). Creating a diverse, inclusive, and equitable learning environment to support children of color’s early introductions to

STEM. *Translational Issues in Psychological Science, 7*(4), 473–486. https://doi.org/10.1037/tps0000313

Funk, C. (2022). *Black Americans' views of and engagement with science.* Pew Research Center. https://www.pewresearch.org/science/2022/04/07/black-americans-views-of-and-engagement-with-science/

Garcia-Holgado, A. (2020). Gender equality in STEM programs: A proposal to analyse the situation of a university about the gender gap. *2020 IEEE Global Engineering Education Conference (EDUCON), (27-30 April 2020, Porto, Portugal)* (pp. 1824–1830). IEEE.

Garrison, H. (2013). Underrepresentation by race-ethnicity across stages of U.S. science and engineering education. *CBE–Life Sciences Education, 12*, 357–363. https://doi.org/10.1187/cbe.12-12-0207

Hand, S., Rice, L., & Greenlee, E. (2017). Exploring teachers' and students' gender role bias and students' confidence in STEM fields. *Social Psychology of Education, 20*, 929–945. https://doi.org/10.1007/s11218-017-9408-8

Hawe, P., Shiell, A., & Riley, T. (2009). Theorising interventions as events in systems. *American Journal of Community Psychology, 43*(3–4), 267–276. https://doi.org/10.1007/s10464-009-9229-9

Hawkins, I., Ratan, R., Blair, D., & Fordham, J. (2019). The effects of gender role stereotypes in digital learning games on motivation for STEM achievement. *Journal of Science Education and Technology, 28,* 628–637. https://doi.org/10.1007/s10956-019-09792-w

Hübner, N., Wille, E., Cambria, J., Oschatz, K., Nagengast, B., & Trautwin, U. (2017). Maximizing gender equality by minimizing course choice options? Effects of obligatory coursework in math on gender differences in STEM. *Journal of Educational Psychology, 109*(7), 993–1009. https://doi.org/10.1037/edu000183

Joseph, S., Arar, K., Karaburk, H., & Elbedour, S. (2023). Superintendents as social justice advocates for African American female students in STEM. *International Journal of Leadership in Education*, 1-19.

Jugović, I. (2017). Students' gender-related choices and achievement in physics. *CEPS Journal, 7*(2), 71–95. https://files.eric.ed.gov/fulltext/EJ1145817.pdf

Juszkiewicz, J. (2021, May 20). Washington watch: Recent federal STEM grant opportunities. *Community College Daily.* https://www.ccdaily.com/2021/05/washington-watch-recent-federal-stem-grant-opportunities

Kanny, M. A., Sax, L. J., & Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: How explanations for the gender gap have evolved over time. *Journal of Women and Minorities in Science and Engineering, 20*(2), 127–148. https://doi.org/10.1615/JWomenMinorScienEng.2014007246

Kennedy, B., Tyson, A., & Funk, C. (2022, February 15). *Americans' trust in scientists, other groups declines.* Pew Research Center. https://www.pewresearch.org/science/2022/02/15/americans-trust-in-scientists-other-groups-declines/

Kozan, S., Blustein, D. L., Barnett, M., Wong, C., Connors-Kellgren, A., Haley, J., Patchen, A., Olle, C., Diemer, M. A., Floyd, A., Tan, R. P. B., & Wan, D. (2017). Awakening, efficacy, and action: A qualitative inquiry of a social justice-infused, science education program. *Analyses of Social Issues and Public Policy, 17*(1), 205–234. https://doi.org/10.1111/asap.12136

Kuchynka, S. L., Eaton, A., & Rivera, L. M. (2022). Understanding and addressing gender-based inequities in STEM: Research synthesis and recommendations for U.S. K-12 education. *Social Issues and Policy Review, 16*(1), 252–288. https://doi.org/10.1111/sipr.12087

Law, F., McGuire, L., Winterbottom, M., & Rutland, A. (2021). Children's gender stereotypes in STEM following a one-shot growth mindset intervention in a science museum. *Frontiers in Psychology, 12,* Article 641695. https://doi.org/10.3389/fpsyg.2021.641695

Lewis, K. L., Stout, J. G., Finkelstein, N. D., Pollock, S. J., Miyake, A., Cohen, G. L., & Ito, T. A. (2017). Fitting in to move forward: Belonging, gender, and persistence in the physical sciences, technology, engineering, and mathematics (pSTEM). *Psychology of Women Quarterly, 41*(4), 420–436. https://doi.org/10.1177/0361684317720186

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education, 4,* Article 60. https://doi.org/10.3389/feduc.2019.00060

Mann, A., & DiPrete, T. A. (2016). The consequences of the national math and science performance environment for gender differences in STEM aspirations. *Sociological Science, 3,* 568–603. https://doi.org/10.15195/v3.a25

Masten, A.S. (2001). Ordinary magic: Resilience processes in development. *American Psychologist, 56*(3), 227–238. https://doi.org/10.1037/0003-066X.56.3.227

Masten, A. S., & Coatsworth, J. D. (1998). The development of competence in favorable and unfavorable environments: Lessons from research on successful children. *American Psychologist, 53*(2), 205–220. https://doi.org/10.1037//0003-066x.53.2.205

Mau, W., Chen, S., Li, J., & Johnson, E. (2020). Gender difference in STEM career aspiration and social-cognitive factors in collectivist and individualist cultures. *Administrative Issues Journal: Connecting Education, Practice, and Research, 10*(1), 30–45. https://doi.org/10.5929/2020.10.1.3

McKinnon, M., & O'Connell, C. (2020). Perceptions of stereotypes applied to women who publicly communicate their STEM work. *Humanities & Social Sciences Communications, 7*, Article 160. https://doi.org/10.1057/s41599-020-00654-0

Mcleod, S. (2023, February 20). *Bronfenbrenner's ecological systems theory.* Simply Psychology. https://simplypsychology.org/Bronfenbrenner.html

Merriam-Webster. (n.d.). Ecology. In *Merriam-Webster.com dictionary.* Retrieved April 4, 2023, from https://www.merriam-webster.com/dictionary/ecology

Mim, S. A. (2019). Women missing in STEM careers: A critical review through the gender lens. *Journal of Research in Science, Mathematics and Technology Education, 2*(2), 59–70. https://doi.org/10.31756/jrsmte.221

Mullet, D. R., Rinn, A. N., & Kettler, T. (2017). Catalysts of women's talent development in STEM: A systematic review. *Journal of Advanced Academics, 28*(4), 253–289. https://doi.org/10.1177/1932202X17735305

National Science Board. (2015). *Revisiting the STEM workforce: A companion to Science and Engineering Indicators 2014*. National Science Foundation

Nobel Prize awards by gender in each category. (2022, November 19). Areppim. https://stats.areppim.com/stats/stats_nobel_sexxcat.htm

Perez-Felkner, L. (2019). Conceptualizing the field: Higher education research on STEM gender gap. *New Directions for Instruction Research, 179,* 11–26. https://doi.org/10.1002/ir.20273

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., & Gary, S. (2009). The contribution of HBCUs to the preparation of African American women for STEM careers: A case study. *Research in Higher Education, 50,* 1–23. https://doi.org/10.1007/s11162-008-9110-y

Rogers-Chapman, M. F. (2014). Accessing STEM-focused education: Factors that contribute to the opportunity to attend STEM high schools across the United States. *Education and Urban Society, 46*(6), 716–737. https://doi.org/10.1177/0013124512469815

Ruppar, A. L., Allcock, H., & Gonsier-Gerdin, J. (2016). Ecological factors affecting access to general education content and contexts for students with significant disabilities. *Remedial and Special Education, 38*(1), 1–11. https://doi.org/10.1177/0741932516646856

Rutherford, A. (2020). Doing science, doing gender: Using history in the present. *Journal of Theoretical and Philosophical Psychology*, *40*(1), 21–31. https://doi.org/10.1037/teo0000134

Schmader, T., Johns, M., & Barquissau, M. (2004). The costs of accepting gender differences: The role of stereotype endorsement in women's experience in the math domain. *Sex Roles, 50*(11–12), 835–850. https://doi.org/10.1023/B:SERS.0000029101.74557.a0

Settles, I. H. (2014, October). Women in STEM: Challenges and determinants of success and well-being. *Psychological Science Agenda.* https://www.apa.org/science/about/psa/2014/10/women-stem

Settles, I. H., O'Connor, R. C. O., & Yap, S. C. Y. (2016). Climate perceptions and identity interference among undergraduate women in STEM: The protective role of gender identity. *Psychology of Women Quarterly,* *40*(4), 488–503. https://doi.org/10.1177/0361684316655806 Simon, R. M., Wagner, A., & Killion, B. (2017). Gender and choosing a STEM major in college: Femininity, masculinity, chilly climate, and occupational values. *Journal of Research in Science Teaching, 54*(3), 299–323.

Sparks, D. M. (2017). Navigating STEM-worlds: Applying a lens of intersectionality to the career identity development of underrepresented female students of color. *Journal for Multicultural Education*, *11*(3), 162-175.

Steward, T. (2013). *The role of leadership in implementation of STEM education in nine western Wisconsin school districts* (Doctoral dissertation, University of Wisconsin–Stout). http://www2.uwstout.edu/content/lib/thesis/2013/2013stewardt.pdf

Stipanovic, N., & Woo, H. (2017). Understanding African American students' experiences in STEM education: An ecological systems approach. *The Career Development Quarterly, 65,* 192–206. https://doi.org/10.1002/cdq.12092

Stoet, G., & Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science, 29*, 581–593. https://doi.org/10.1177/0956797617741719

Stone, W. (2021). *An anti-vaccine film targeted to Black Americans spreads false information.* NPR. https://www.npr.org/sections/health-shots/2021/06/08/1004214189/anti-vaccine-film-targeted-to-black-americans-spreads-false-information

Stout, J. G ., Dasgupta, N., Hunsinger, M., & McManus, M. A. (2011). STEMing the tide: Using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology, 100*(3), 255–270. https://doi.org/10.1037/a0021385

Stout, J. G., Grunberg, V. A., & Ito, T. A. (2016). Gender roles and stereotypes about science careers help explain women and men's science pursuits. *Sex Roles, 75*, 490–499. https://doi.org/10.1007/s11199-016-0647-5

United Nations Educational, Scientific and Cultural Organization. (1999). *Declaration on science and the use of scientific knowledge and the science agenda: Framework for action.* https://unesdoc.unesco.org/ark:/48223/pf0000116994

U.S. Department of Education. (2022, December 7). *U.S. Department of Education launches new initiative to enhance STEM education for all students* [News release]. https://www.ed.gov/news/press-releases/us-department-education-launches-new-initiative-enhance-stem-education-all-students

U.S. Department of Education. (n.d.). *U.S. Department of Education STEM investments FY18-20.* https://www.ed.gov/sites/default/files/documents/stem/stem-investments-18-20.pdf

Wang, M., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review, 29*, 119–140. https://doi.org/10.1007/s10648-015-9355-x

Watson, S., Williams-Duncan, O. M., & Peters, M. L. (2020). School administrators' awareness of parental STEM knowledge, strategies to promote STEM knowledge, and student STEM preparation. *Research in Science & Technological Education, 40*(1), 1–20. https://doi.org/10.1080/02635143.2020.1774747

World Economic Forum. (2016). *Human capital report 2016.* https://reports.weforum.org/human-capital-report-2016/

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual Review of Sociology, 41*, 331–357. https://doi.org/10.1146/annurev-soc-071312-145659

Young, J. L., Ero-Tolliver, I., Young, J. R., & Ford, D. Y. (2017). Maximizing opportunities to enroll in advanced high school science courses: Examining the scientific dispositions of Black girls. *Journal of Urban Learning, Teaching, and Research, 13,* 174–183.

Zhang, L., & Barnett, M. (2015). How high school students envision their STEM career pathways. *Cultural Studies of Science Education, 10*, 637–656. https://doi.org/10.1007/s11422-013-9557-9