

Understanding and Addressing Gender-Based Inequities in STEM: Research Synthesis and Recommendations for U.S. K-12 Education

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We draw from ecological systems and social psychological theories to elucidate macrosystem- and microsystem-level variables that promote and maintain gender inequities in science, technology, engineering, and math (STEM). Because gender-STEM stereotypes undermine girls' (and women's), but boosts boys' (and men's), STEM interest and success, we review how they operate in STEM learning environments to differentially socialize girls and boys and undermine gender intergroup relations. We propose seven practice recommendations to improve STEM K-12 education: (1) design relational classrooms, (2) teach the history of gender inequality and bias, (3) foster collaborative and cooperative classrooms, (4) promote active learning and growth mindset strategies, (5) reframing STEM as inclusive, (6) create near-peer mentorship programs, and (7) re-imagine evaluation metrics. To support these practice recommendations, three policy recommendations are posited: (1) increase teacher autonomy, training, and representation,

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(2) *re-evaluate standardized testing, and (3) reallocate and increase government funding for public schools.*

The last three decades have witnessed an increase in science, technology, engineering, and math (STEM) outreach programs and interventions in the United States (Ashley et al., 2017; Clewell et al., 2005; Kuchynka et al., 2020; van den Hurk et al., 2019), yet gender and ethnic-racial inequities persist (National Science Foundation, National Center for Science and Engineering Statistics, 2019). Relative to men, women are retained less in STEM training and occupy the STEM labor force in lower numbers, with even lower proportions among ethnic-racial minority women (National Science Foundation, National Center for Science and Engineering Statistics, 2019). Specifically, women in the United States have increased their labor participation in STEM from 8% in 1970 to 27% in 2019, but they comprise 48% of the U.S. labor force (Martinez & Christnacht, 2021). Also, of the 27% of women STEM workers, only 5% consist of women of color (Martinez & Christnacht, 2021).

Increasing the recruitment and retention of underrepresented gender and ethnic-racial groups (URGs) in STEM training and careers yields numerous societal benefits for the United States and abroad. First, it ameliorates general labor shortages in STEM (National Science Board, 2015). Second, it provides URG individuals with an opportunity to hold high-status positions in STEM (e.g., engineers, professors; Davis, 1989; National Science Board, National Science Foundation, 2021). Third, it stimulates global competition and leadership in STEM innovation and productivity (Griffith, 2010; Marginson et al., 2013; National Science Board, 2015). And, finally, it promotes both sustained and sustainable economic growth, which is vital to building wealth and achieving economic justice (National Science Board, 2015).

To achieve gender and gender-by-ethnic-racial equity in STEM, we must first understand the root causes preventing it. To this end, we review research on gender-STEM disparities in K-12 education in the United States, using a framework inspired by Bronfenbrenner's (2005) ecological systems theory. Ecological systems theory posits that children develop in nested systems that continuously influence each other. Our framework features two system levels—the macrosystem and the microsystem—and draws from social psychological theories and research to understand the social and structural variables that independently and in tandem prevent STEM gender and gender-by-ethnic-racial parity. As a preview, Figure 1 illustrates the macrosystem which is composed of intergroup structures and cultural-level ideologies and stereotypes shaped by social roles, social dominance, and system justification. Concurrently, the microsystem is composed of interpersonal interactions among teachers, parents, and students driven by individual-level explicit and implicit biases and stereotypes, expectations and attributions, and identity threats in STEM learning environments.

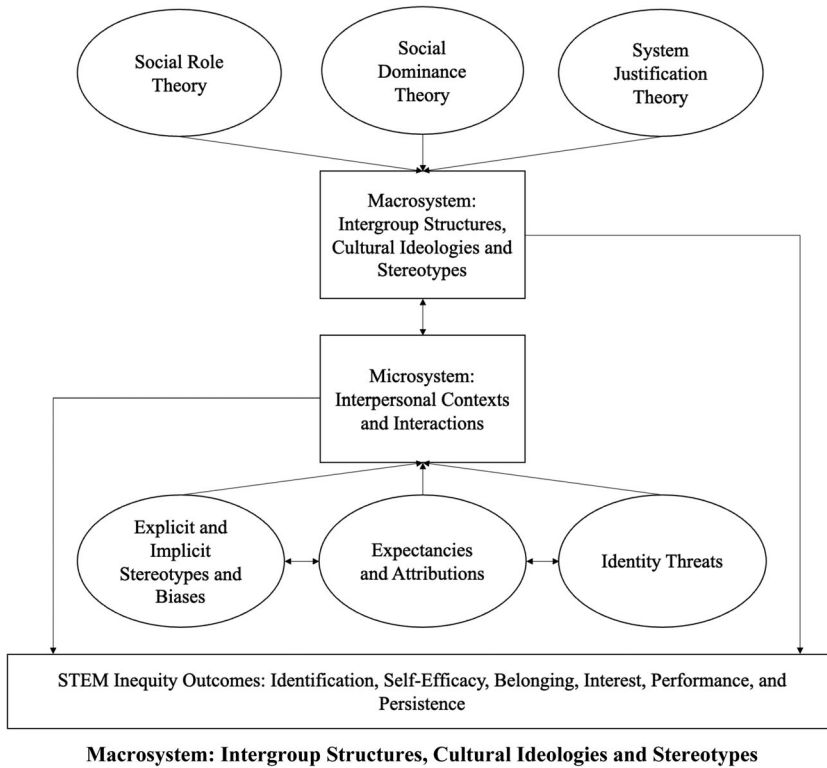


Fig 1. A social psychology framework of macrosystem and microsystem variables underlying gender-based STEM inequities.

This review focuses on K-12 STEM learning environments, placing the onus on structures and intergroup relations to address the social psychological needs and experiences of *both* girls and boys. Specifically, cultural stereotypes about girls and women in STEM—that girls and women lack STEM abilities compared to boys and men and that STEM fields are masculine as opposed to feminine—develop and are maintained by macrosystem ideologies, then manifest in each aspect of microsystem environments. Because gender-STEM stereotypes are like a two-face coin—undermining girls’ (and women’s) interest and performance while boosting boys’ (and men’s)—it is imperative to examine how gender stereotypes influence both girls’ and boys’ STEM cognition (e.g., identity) and behavior (e.g., performance, persistence).

Finally, our review draws from our framework and the research supporting it to make practice and policy recommendations for changing K-12 STEM learning

environments to support and optimize success among both girls and boys. The practice recommendations center on ways to increase gender egalitarianism, intergroup cooperation, and collaboration in STEM K-12 learning environments. To support these practice recommendations, three policy recommendations are posited: (1) increase teacher autonomy, high-quality training, and representation, (2) re-evaluate standardized testing, and (3) reallocate government funding for public schools.

Macrosystem: Intergroup Structures, Cultural Ideologies, and Stereotypes

According to Bronfenbrenner's ecological systems theory, the macrosystem represents the established culture in which individuals develop (Bronfenbrenner, 2005). An individual's development is influenced by the culture's intergroup structures, ideologies, and stereotypes at the macrosystem level because they shape the beliefs and values of individuals living in that culture (and manifesting at the microsystem level). As depicted in Figure 1, three well-established macrosystem-level theories in social psychology explain how cultural socialization creates an ideological consensus that strongly associates STEM competence with boys, men, and masculinity as opposed to girls, women, and femininity. Specifically, (1) social role theory (Eagly & Steffen, 1984; Eagly & Wood, 2011) explains why gender-STEM stereotypes are pervasive across culture, (2) social dominance theory (Sidanius et al., 1994) details why men are motivated to endorse and disseminate gender-STEM stereotypes, (3) and system justification theory (Jost & Banaji, 1994) describes why women are also motivated to endorse gender-STEM stereotypes and ideologies that devalue their ingroup. Together, these theories demonstrate how cultural stereotypes fuel differential socializations of girls and boys during K-12 that result in disparate STEM outcomes.

We acknowledge from the outset that the macrosystem factors and processes in this review are moderated by girls' and women's intersecting identity-based experiences in STEM. However, most research to date on gender and STEM, especially in the K-12 realm, has examined disparities through the single axis of gender oppression. Nonetheless, throughout this review we aim to draw from, whenever possible, the emerging work on how gender and ethnicity-race co-act to stifle the success of girls and women of color in STEM and elevate the success of White and Asian boys and men. The concept that individuals' experiences are a function of unique, interlocking, and co-constructed social identities (e.g., race, ethnicity, sexuality, class, ability, and gender) that result in complex interactions is known as Intersectionality Theory (Cole, 2009; Crenshaw, 1989, 1991). With a focus on the interrogation of power in society (Warner et al., 2016), intersectionality theory points out that sexism and racism, for example, converge to result in multidimensional and unique experiences of oppression for women and girls of color (Crenshaw, 1991). To illustrate the complex nature of intersectionality in

STEM, recent research suggests that gender imbalances in STEM are primarily driven by gender role norms among White and affluent families, because Black girls typically outperform their Black male peers (Dossi et al., 2021). These findings indicate that gender gaps in STEM are not “natural” and “inevitable,” but instead reflect a deeply entrenched system of gender, race, ethnicity, power, and privilege. Thus, intersectionality conditions all of the theories and empirical data in our framework (Figure 1), reminding us that single-axis examinations of social identity and power erase the experiences of women and girls of color by failing to understand the interactions between multiple forms of oppression.

Social Role Theory

Social role theory argues that the distribution of men and women into different social roles maintains gender stereotypes, or consensually shared beliefs about men and women’s attributes (Eagly & Steffen, 1984; Eagly & Wood, 2011). Men are more likely to hold high-status, agentic positions in society, and women are more likely to hold low-status, domestic positions. These differences, referred to as the gender division of labor, result in stereotypes that link men to dominance and competence and women to communion and support. Moreover, boys and men are socialized to pursue agentic goals (e.g., earning resources, focusing on individual achievement) and girls and women are socialized to pursue communal goals (e.g., domestic work, child-rearing, caring for others; Eagly & Steffen, 1984). As a result, and even with women’s increased representation in the U.S. labor force over the last 50 years, a gender division in paid labor persists in which women take on more low-status, communal work that pays less, such as early childhood and elementary school teachers (The World Bank, 2020).

Since men have historically occupied the majority of STEM careers in the United States (e.g., computer scientists are 74% male; National Science Foundation, National Center for Science and Engineering Statistics, 2019), social role theory posits it is one reason why men and masculinity, as opposed to women and femininity, are strongly linked to STEM (Carli et al., 2016). Interestingly, these gender-STEM stereotypes continue to be perpetuated and widely endorsed even though empirical reviews consistently indicate that girls and women exhibit stronger STEM academic performances than boys and men (Bloodhart et al., 2020; Stoet & Geary, 2018; Voyer & Voyer, 2014). Although girls and women get lower scores than boys and men on standardized tests including the Scholastic Aptitude Test (Wainer & Steinberg, 1992), girls get higher grades than boys in K-12 science and math classes (Voyer & Voyer, 2014), and women get higher grades than men in college STEM courses (Bloodhart et al., 2020). Indeed, women’s superior STEM academic performance is consistent across most countries (Stoet & Geary, 2018). Thus, gender-STEM stereotypes are inaccurate, yet they continue

to pervade the macrosystem and influence cultural ideologies and intergroup relations.

Social role theory can also be interpreted through a lens of intersectionality. Individuals with multiple identities are frequently overrepresented in particular social roles in society, which affects perceivers' beliefs about their attributes (Koenig & Eagly, 2014). Koenig and Eagly (2014) demonstrated, for example, that community and student samples perceive Black women in the United States as typically occupying jobs low in competence and high in communion, like secretaries, food service workers, or cleaning service workers, while jobs like engineer and computer scientist were perceived as more common among Arab and Asian women. Indeed, Black women were overrepresented in these roles compared to other groups in the United States (Koenig & Eagly, 2014). Most significantly, however, was that groups' typical roles influenced participants' group stereotypes. Thus, the overrepresentation of Black women in low-competence roles in society is likely to affect people's beliefs about the ability of girls and women of color to achieve success in STEM jobs.

One example of how gender-STEM and gender-by-race-ethnicity STEM stereotypes seep into STEM learning environments can be found in the representation of women and women of color in STEM textbooks relative to those actually represented in the U.S. labor force. Investigations of chemistry, physics, and biology textbooks have all uncovered racial and gender bias, with women scientists and scientists of color being represented at rates lower than their existence in the population and in the STEM labor force (Becker & Nilsson, 2021; King & Domin, 2007; Lawlor & Niiler, 2020; Wood et al., 2020). In one study of the names of people cited in seven popular biology textbooks, there was no representation of Black women and a significant underrepresentation of Latinx and Asian women in any of the textbooks across all editions ranging from 1900 to 2018 (Wood et al., 2020). Lawlor and Niiler (2020) similarly examined images of people in 10 physics textbooks spanning over 50 years, categorizing images by skin tone and gender. They found that the images were mostly images of light-skinned males, and there were "virtually no images of dark-skinned females in any textbook during any year" (p. 321).

Social Dominance Theory

Social dominance theory proposes that high-status groups are motivated to maintain hierarchical relations to preserve their structural power and related psychological benefits (Pratto et al., 2000; Sidanius et al., 1994). For example, research finds that men, relative to women, benefit mentally (e.g., lower levels of depression and neuroticism) and materially (e.g., higher compensation for similar work and more access to high-status careers, relative to women) from living in societies with pervasive ideologies and gender relations that disadvantage women

(Jost et al., 2004). Furthermore, perceived threats to the gender status hierarchy often results in system defenses from men as members of the high-status group (Kosakowska-Berezecka et al., 2020; Kuchynka et al., 2018; Morton et al., 2009).

System defenses include any beliefs or stereotypes that justify, legitimize, or defend gender inequality (Kay et al., 2007). System defenses and status legitimizing actions maintain group-based inequality by imbuing the high-status groups' dominant social position with legitimacy and a sense of fairness (Jost et al., 2004). One common system defense reflects essentialist beliefs about gender that portray women and men as fundamentally and immutably different (Morton et al., 2009). Zero-sum thinking also functions as a system defense, because men believe they will suffer psychologically and materially if women encroach in traditionally masculine domains (Kuchynka et al., 2018). A recent cross-national investigation identified that the endorsement of gender-based zero-sum beliefs predicts men's resistance to gender equality across nations, and, interestingly, this relation is especially true among more gender equal nations like the United States (Kosakowska-Berezecka et al., 2020). Notably, these system defenses are factually inaccurate beliefs, because women and men are not part of discrete gender categories as posited by gender essentialism (Carothers & Reis, 2013) and women's status gains do not inherently come at the expense of men (Kabeer & Natali, 2013).

Social dominance theory can also be applied at identity intersections and explain intersectional inequalities (for a review, see Sidanius et al., 2018). For example, Black women, who are stereotyped as more dominant and confident than White women, do not violate intersectional gender norms when they behave assertively in the workplace, and are not as likely to receive the same backlash from expressing system-defending ideologies, when compared to White women (Livingston et al., 2012; Rosette et al., 2016). However, because Black women are seen as generally low in competence compared to Asian and White women (Rosette et al., 2016), they may be seen as ill-suited for positions requiring intellect, like STEM jobs, and penalized for ambitious agency in which they seek power, which is nonprototypical for their group.

In sum, social dominance research supports the main hypothesis that men (especially White and Asian men in the STEM contexts) are motivated to endorse and distribute system-defense beliefs and actions to create cultural consensus, protect their higher status, and maintain their group's benefits stemming from being perceived as relatively competent in STEM.

System Justification Theory

System justification theory builds on social dominance theory by hypothesizing that *both* low- and high-status group members often endorse beliefs that support the social hierarchy (Jost & Banaji, 1994). One reason for their

motivation to justify social inequality is because it is psychologically uncomfortable to acknowledge that one lives in a society that is systematically unfair (Jost & Banaji, 1994). In the case of gender, system justification theory would predict that women (the low-status group) should support ideologies that disadvantage their own group. Indeed, women also endorse cultural stereotypes and ideologies that favor men to reduce psychological dissonance from living in a society that perpetuates inequitable gender relations (Kay et al., 2007).

As it relates to the gender status hierarchy, system justification theory proposes that people adopt “complementary” stereotypes where agency is attributed to men and communion to women to satisfy perceptions of a fair and legitimate social system (Jost & Kay, 2005). These stereotypes justify the gendered division of labor and, thus, the gender status hierarchy in which women are more likely to take on low-status positions particularly unpaid, domestic, and caretaking responsibilities, while men are more likely to occupy high-status positions in the paid labor force. Because of men’s historic interdependence with women (e.g., heterosexual relationships, child-rearing), sexism rooted in cultural stereotypes manifest as *both* hostile and benevolent (Glick & Fiske, 1996). Hostile sexism is overtly antagonistic (e.g., “women seek to gain power by getting control over men”) and benevolent sexism reflects patronizing treatment of women (e.g., “women should be cherished and protected by men”; Glick & Fiske, 1996). Benevolent sexism is subtle and often times goes unnoticed as a form of bias, but is often more damaging than hostile sexism, because it subtly and indirectly communicates that women lack competence (Barreto & Ellemers, 2005; Dardenne et al., 2007). Indeed, benevolent sexism, compared to hostile sexism, is more strongly associated with negative STEM outcomes (Kuchynka et al., 2018), induces longer-lasting physiological stress responses (Salomon et al., 2015), and impairs cognitive performance (Dardenne et al., 2007).

The more the dominant group (men) relies on the subordinate group (women) for resources, labor, or close relationships, the more stereotypes become prescriptive (i.e., how group members *ought* to behave) in addition to descriptive (i.e., how group members *typically* are). Prescriptive and proscriptive (i.e., how group members should not behave) stereotypes satisfy the high-status group’s motivation to maintain inequality by creating cultural rules for low-status group members’ behaviors (Glick & Fiske, 1999). Consequently, girls and women who exhibit agentic behaviors challenge traditional gender intergroup relations and often experience backlash, while men are rewarded for displaying comparable behaviors (Rudman & Phelan, 2008). Thus, consistent with system justification theory, gender-based stereotypes that link STEM competence with men and masculinity reflect people’s desires for men, compared to women, to pursue and persist in STEM, while also satisfying people’s perceptions of a fair gender system.

Summary

By combining the tenets of social role, social dominance, and system justification theories, and further examining them through a lens of intersectionality, we seek to address the nuanced socialization of girls and boys that simultaneously results in inequitable intergroup interactions and girls' lack of persistence in STEM. Social role theory posits the gender division of labor fosters intergroup relations characterized by inequitable group dynamics that afford men more status and authority and that socialize women, including women of color, to embody and adopt caretaking roles and roles that require low levels of competence. Social dominance theory details how men, the dominant group, create ideological consensus that their ingroup is better suited for high-status roles such as those in STEM. System justification theory explains why gender stereotypes are unique and difficult to challenge, because both high- and low-status groups (including women) are motivated to support traditional gender relations and to maintain the illusion of a fair society. Collectively, these theories demonstrate how cultural stereotypes at the macrosystem level uphold the gender status hierarchy and differentially socialize boys and men and girls and women. Next, we detail how gender hierarchies and status beliefs are continuously recreated through day-to-day interactions at the microsystem level.

Microsystem: Interpersonal Contexts and Interactions

The microsystem system represents an individual's immediate environment during development (Bronfenbrenner, 2005). As depicted in Figure 1, the social structure of the macrosystem generates cultural stereotypes and ideologies that manifest explicitly and overtly (e.g., girls hearing negative comments about their STEM ability) and implicitly and subtly (e.g., parents using less scientific language with daughters compared to sons) among important social agents (Kim et al., 2018), which drive differential expectancies and attributions for boys and girls (LaCosse et al., 2016), and create environments that are identity threatening to girls and identity affirming for boys (Spencer et al., 2016).

Explicit and Implicit Biases

Biases are a set of beliefs, attitudes, and behavioral actions toward or against one or more individuals based on the group with which they identify or the group with which they are perceived to belong to (Dovidio et al., 2010). One characterization of biases is stereotypes, which are generalized beliefs that mentally associate qualities and characteristics with most or all members of a social group or that most or all members of a social group are the same (e.g., all men are good at STEM). Implicit stereotypes are the consequence of the automatic activation of

these associations, and explicit stereotypes reflect conscious endorsement of these associations (Nosek et al., 2002). Moreover, implicit stereotypes are developed through repeated exposure to cultural stereotypes in the macrosystem (Greenwald & Krieger, 2006). Even when individuals are not aware of their implicit stereotypes, they directly influence personal behavior (De Houwer, 2019). Girls who endorse relatively strong implicit math-male stereotypes express more negative attitudes toward math, have lower math participation, and worse math achievement (Nosek & Smyth, 2011). At the country level, implicit gender stereotypes predict gender gaps in STEM test performance, revealing the undetectable and pernicious nature of implicit bias at the macrosystem level (Nosek et al., 2009).

Importantly, stereotypes about gender and STEM ability also depend on the target's race-ethnicity. Asian American women, by virtue of their race-ethnicity, are stereotyped as innately good at STEM (Castro & Collins, 2021). Relating back to social role theory, this may be due to the fact that Asians are overrepresented in STEM education and industry in the United States since World War II (Xie & Goyette, 2003). Black women and girls, however, are stereotyped as low-performers in STEM (for a review, see Joseph et al., 2017). Next, we detail how explicit and implicit stereotypes manifest in biased behaviors (i.e., preference for boys in STEM domains) among three socializing human agents in the microsystem—teachers, parents, and peers.

Socializing agents: teachers, parents, and peers. Teachers (Copur-Gencturk et al., 2020), parents (Kim et al., 2018), and male peers (McGuire et al., 2020) endorse associations that link STEM competence and brilliance to men and masculinity. Teachers demonstrate implicit gender and racial stereotypes when evaluating student math performance—they favor White and male students (Copur-Gencturk et al., 2020). Teachers also endorse explicit stereotypes that associate boys more strongly with innate math ability than girls' (Tiedemann, 2000, 2002; Hand et al., 2017). K-8 teachers who associate mathematics with brilliance also tend to think that girls are less adept at math than boys (Copur-Gencturk et al., 2020). Finally, the gender identity of teachers may influence girls' and boys' STEM interest and self-efficacy (Sansone, 2017). Men teachers are more likely than women teachers to endorse beliefs about boys' superior STEM abilities and treat boy and girl students differently, and these beliefs and behaviors contribute to deficits in STEM-related social psychological variables (Sansone, 2017).

Parents display biases similar to those of teachers (Kim et al., 2018). Parents in the United States verbally encourage their male children to participate more in STEM-related activities than their female children (Eccles, 2015) and tend to use more scientific and cognitively complex language with sons compared to daughters (Tenenbaum & Leaper, 2003; for a thorough review of teachers and parents' STEM-related gender biases, see Kim et al., 2018).

Boy peers are also a main source of biased treatment in K-12 STEM domains (Brown & Leaper, 2010; Greenfield, 1996; Leaper & Brown, 2008; Mulkey, 1989; Stake, 2003), presumably because girls who are interested or perform well in STEM domains challenge the assumption that STEM is a masculine domain and threaten the gender status hierarchy. As early as second grade, boys across ethnicities in the United States exhibit implicit and explicit STEM stereotypes that link math with boys and masculinity (Cvencek et al., 2011; Greenfield, 1996), and, as early as kindergarten, boys demonstrate negative beliefs about women's science abilities (Mulkey, 1989). Boys with low STEM confidence resist efforts to increase girls' and women's participation in STEM, suggesting that boys react negatively to women in STEM as a way to boost their self-esteem and status (Stake, 2003).

Girls, meanwhile, report that male peers are the most frequent perpetrator of bias against them in academic domains, including negative comments about their math and science abilities (Leaper & Brown, 2008). Repeated messages that girls and women lack STEM competence is an effective way to prevent women from occupying or succeeding in STEM (Casad et al., 2019). Indeed, among girls, frequent experiences with negative STEM messages are associated with reduced interest in STEM (Brown & Leaper, 2010) and lower STEM achievement (Leaper & Brown, 2014). These findings are consistent with research on the importance of peer influence for developing domain-specific identities, beliefs, and intentions (Robnett & Leaper, 2013). Indeed, girls who are immersed in female peer groups that value STEM express stronger personal STEM values (Crosnoe et al., 2008; Jones et al., 2012; Nelson & DeBacker, 2008) and STEM career aspirations (Robnett & Leaper, 2013).

Expectancies and Attributions

Gender-STEM stereotypes create expectations that boys and men are more innately talented in STEM than girls, and lead people to make different attributions for boys success and girls failures in STEM (Eccles, 1994; Eccles et al., 1999). Parents expect their daughters to struggle more in STEM careers than their sons (Eccles, 2015), and overestimate their sons', but underestimate their daughters', STEM abilities, which predicts their children's self-efficacy and interest in STEM (Tenenbaum & Leaper, 2003). Furthermore, parents' beliefs about their children's math abilities predict perceptions of children's own math ability and future success in math above and beyond children's academic grades (Frome & Eccles, 1998).

Research on attribution bias demonstrates that people tend to endorse external explanations (working hard) for girls' success in STEM and internal explanations (innate ability) for boys' (LaCosse et al., 2016). When STEM environments are perceived as unwelcoming for women, women endorse attributions that link

women's failures in STEM to low ability and men's failures to unfavorable circumstances (LaCosse et al., 2016). In turn, women who endorse these STEM attributions express weaker intentions to pursue STEM (LaCosse et al., 2016). The tendency to attribute women's failures in STEM to task difficulty and men's failures to bad luck and lack of effort is consistently observed across samples (Swim & Sanna, 1996). Even parents attribute their daughters' higher grades in math classes and math tests than their sons' to working harder instead of talent (Eccles, 2015). Middle school girls from ethnic-racial minority groups often experience lose-lose situations in which working hard is perceived as a threat, but not working hard enough is perceived as lacking competence (Robinson et al., 2016). Among women, these attributions result in a heightened sensitivity to failure on math tests, which in turn reduces math persistence on follow-up math problems (Kiefer & Shih, 2006).

Identity Threats

Identity threats refer to when individuals from a socially disadvantaged, underrepresented, or stigmatized group are in situations in which they are negatively influenced by negative stereotypes about their group (Branscombe et al., 1999). Girls and women continuously receive (explicit and implicit) messages that undermine their STEM self-concept, thus activating the category gender in STEM contexts. For example, the underrepresentation of women and women of color in STEM textbooks may lead girls and women to feel threatened by the prospect of confirming their group's stereotype, resulting in their underperformance (Block et al., 2019; Shapiro & Williams, 2012; Spencer et al., 2016). Indeed, Good et al. (2010) demonstrated that women students performed better on tests of their understanding of chemistry lessons when those lessons included pictures of women than when the lessons included pictures of men. Notably, the mere act of taking a test in STEM is enough to trigger stereotype threat for girls (Walton & Cohen, 2003). Boys, however, regularly receive messages about their superior STEM competence and situations that lead to a "stereotype lift," which is when the performance of an individual from a nonstereotyped group is enhanced after a negative stereotype links the stereotyped group to an intellectual test (Spencer et al., 2016; Walton & Cohen, 2003).

STEM-based identity threat effects among girls also depend on their ethnic-racial background. In many situations, women and girls from ethnic-racial stereotyped groups experience "double jeopardy" from the multiplicative experience of gender and racial biases (Carter, 1988), including perceiving more discrimination than their White or male counterparts (Eaton et al., 2020; Hurtado et al., 2012). Physics faculty rate Latinx and Black women as less hireable than White men and women applicants (Eaton et al., 2020). Ethnic-racial minority women faculty in STEM report experiencing more instances of subtle forms of bias compared to

their male and White faculty counterparts (Hurtado et al., 2012). Similarly, among White, Asian, and Black STEM college students, Black women report the weakest belonging in STEM, and White men report the strongest belonging in STEM (Rainey et al., 2018). And in the context of stereotype threat, the double minority status of Latinx women leads to reduced performance on math and spatial tests when either gender or ethnicity is salient (Gonzales et al., 2002). Therefore, improving girls' and women's experiences in STEM depends upon identifying and addressing forms of gendered racism and their short- and long-term impacts.

In the United States, standardized testing is compulsory throughout K-12 to assess math (and reading) ability and for college and graduate school admissions. The cultural emphasis on standardized testing creates high-stakes environments for learning STEM material where students (and teachers) are consistently under pressure to do well on tests (McNeil, 2000). Priming competition in STEM results in stronger fear of confirming negative gender-STEM stereotypes among girls (Van Loo et al., 2013). Testing-focused environments also activate cultural stereotypes and heighten anxiety in girls, affecting their classroom performance (Appel et al., 2011). Girls and boys engage in math self-assessments that bias girls to underestimate (Correll, 2001), but bias boys to overestimate (Sáinz et al., 2020), their abilities. Relatedly, girls endorse a higher STEM "standards gap" than boys, which refers to how girls require stronger performances in math and science to develop positive STEM attitudes and intentions to pursue STEM, which predicts gender imbalances in STEM observed among more gender equal countries (Mann & DiPrete, 2016). To illustrate, if an elementary or middle school girl receives an underwhelming score on a math standardized test, she will likely view this as an indictment of her innate STEM ability and decide to avoid STEM material. Finally, standardized college entrance exams like the SAT (formerly known as the Scholastic Aptitude Test, then the Scholastic Assessment Test) in the United States underpredict women's college grades compared to men, thereby promoting gender imbalances in STEM (Leonard & Jiang, 1999). Also, Latinx and Black girls' SAT performance is typically lower than that of Asian and White girls (Everson & Millsap, 2004). Thus, standardized testing creates high-stressed learning environments that undermine diverse girls' and women's STEM aptitude.

Summary

As depicted in Figure 1, the combination of experiencing explicit and implicit bias, identity threats, and differential expectancies and attributions throughout childhood, lead girls to develop more STEM-based psychological deficits by middle school, such as increased STEM anxiety (Blazer, 2011; Geist, 2010), lower self-efficacy (beliefs about one's abilities in a specific domain; Seegers & Boekaerts, 1996; Stewart et al., 2020), weaker STEM identities (Cvencek et al., 2011), and lower STEM career aspirations (Kim et al., 2018), when compared to

boys. However, and interestingly, girls outperform boys in STEM classes during primary, secondary, and higher education (Bloodhart et al., 2020; Eccles, 2015; Voyer & Voyer, 2014). Thus, gender gaps in STEM pathways are most likely driven by differential socialization of boys and girls as opposed to differences in aptitude.

One suggestion to increase gender parity in STEM is to equitably socialize girls and boys in STEM, providing adequate support and encouragement to pursue STEM throughout childhood, and cultivating egalitarian STEM values that undermine intergroup competition and instead foster collaboration. Unfortunately, this is not an easy task, because the endorsement of STEM stereotypes among social agents in the microsystem are often implicit and subtle. Parents and teachers may not even be aware that they possess gender-STEM stereotypes. On top of that, parents and boy peers are often motivated to downplay girls' and upplay boys' STEM competence to maintain unequal gender relations that grant men more authority and status (Frome & Eccles, 1998; Stake, 2003). However, these detrimental outcomes are not obligatory if children in K-12 are socialized in classroom and nonclassroom environments that emphasize egalitarianism and intergroup cohesion.

STEM Education and Policy Recommendations

Given the above empirical literature, the remainder of our review puts forth a set of STEM education practice and policy recommendations that create cohesive, inclusive, and collaborative STEM K-12 environments. The current social structure of the United States produces unequal gender relations among the microsystem, which in turn reinforce macrosystem ideologies and cultural stereotypes. Accordingly, the bulk of our education and policy recommendations are aimed at changing the structure of STEM learning environments to be more adaptive for both girls and boys in K-12, thereby cultivating equitable intergroup interactions at the microsystem level. The recommendations aim to target and ameliorate environmental forces that result in girls' heightened STEM anxiety, reduced self-efficacy, and weaker career aspirations, as well as address gender imbalances in STEM education and professions. A related goal of the following educational recommendations is to improve gender relations across K-12 STEM environments. Both boys and girls will yield benefits from being immersed in collaborative STEM environments that emphasize forming meaningful relationships and learning how to work together to achieve common goals. Thus, we emphasize intergroup cohesion and positive interactions instead of developing gender segregated classrooms, because there is no evidence that K-12 school-based gender segregation improves girls' STEM outcomes (Pahlke et al., 2014; Signorella et al., 2013), and instead may actually increase STEM stereotypes (Martin et al., 2014). Though the following education recommendations are designed to improve

STEM environments, each recommendation, theoretically, should help improve gender and ethnic–racial relations across learning environments.

Each of our educational recommendations are rooted in the success of STEM outreach and intervention programs targeting students from underrepresented groups. There is overwhelming evidence demonstrating the positive impact of STEM outreach and intervention programs on girls' and ethnic–racial minority students' STEM outcomes (for reviews, see Chun & Harris, 2011; Kuchynka et al., 2020), and reducing stereotype endorsement among boys (Stake, 2003). One primary goal of STEM outreach programs is to allow children to socialize and learn STEM material in informal, nonacademic environments that emphasize the development of personal relationships among peers, mentors, and teachers (Chun & Harris, 2011; Kuchynka et al., 2020), which increases STEM identity, belonging, interest, and intentions (Kuchynka et al., 2020). Stake and Nickens (2005) found that both girls and boys demonstrated long-term increases in envisioning themselves as scientists if they reported positive peer relationships during a STEM outreach program. Relatedly, active learning embedded within STEM outreach programs is also theorized to stimulate stronger engagement with STEM material compared to passive learning in traditional classroom settings (Kuchynka et al., 2021). In sum, STEM outreach and intervention programs present an opportunity to explore STEM material in a low-stakes environment without the pressure of testing. These low-stakes, informal environments are particularly important for students from marginalized groups who fear underperforming in STEM (Chun & Harris, 2011). Thus, we draw from the empirical lessons in this growing outreach and intervention literature to propose the following educational recommendations.

Education Recommendations

Elementary and secondary classrooms in STEM often create dynamics that encourage male dominance and female submissiveness. K-12 STEM classes are often characterized by biased male peers (Riegle-Crumb et al., 2018), scientific discussions dominated by male students (Guzzetti & Williams, 1996), and science textbooks that disproportionately present White men via images and text (Bazler & Simonis, 1991; Delgado, 2008). Given current gender prescriptions that attribute assertive and dominant characteristics to men and submissive characteristics to women (Prentice & Carranza, 2002), these classroom dynamics often seem like natural or inevitable spaces for harmful gender intergroup relations. We propose seven potential solutions to pre-empt unequal gender relations that emerge during K-12: (1) design relational classrooms (2) teach about gender inequities and biases; (3) foster collaboration and cooperation classrooms; (4) promote active learning through the use of mindset strategies; (5) reframing STEM as inclusive; (6) create near-peer mentorship programs; and (7) re-imagine evaluation metrics.

Design relational classrooms. Relational classrooms are characterized by forming meaningful connections among peers and teachers that allow students to feel accepted and encouraged to empathize with one another (Bozkurt & Ozden, 2010; Farber & Penny, 2020). Socialization practices in the United States emphasize individual achievement even if reaching this goal comes at the expense of others, and the need for individual achievement fuels narcissism and defensive behaviors amid perceived threats (Twenge, 2006). Importantly, cooperative learning environments (a key characteristic of relational classrooms) promote academic achievement and productivity far more than interpersonal competition and individualistic efforts (for a meta-analysis, see Johnson et al., 1981). Similarly, small-group peer-learning programs boast more gains in self-efficacy and self-regulation than traditional college courses (Micari & Pazos, 2021). Therefore, classroom dynamics should be constructed in which students work together to achieve common goals and form close relationships, instead of creating goal structures that pit students against one another (also see intergroup contact hypothesis, Pettigrew & Tropp, 2005).

The general idea underlying relational classrooms is to foster healthy civics and ethics among young citizens in addition to increasing their knowledge (Farber & Penney, 2020). To accomplish these tasks, classroom designs and curriculum should continuously reiterate the importance of perspective-taking, which refers to understanding how others' internal states and experiences shape their views and behavior (Heagle & Rehfeldt, 2006). Students should also be taught how learning and innovation are collaborative processes. To that end, teachers can set up social norms for discussions dictating that talking-time should be split evenly among students, and students who may be resistant to talking in class should write down their thoughts in a journal. Teachers should emphasize gender-inclusive classroom norms that promote positive working relations between girls and boys, because they increase women's expectations for positive interactions with men, which reduces feelings of threat (Hall et al., 2018). One specific practice for creating inclusive, relational classrooms is seating designs that allow students to make eye contact with each other during discussions (Mix et al., 2019). In sum, classroom environments should emphasize the importance of forming and maintaining relationships, especially cross-gender (and cross-race) relationships and relying on cooperation as opposed to perceiving intergroup relations as potential threats to personal achievement.

Teaching about gender inequities and biases. To create inclusive classrooms, the objectives of K-12 curriculum in general should include that students will understand gender inequities and learn to address incidences of gender bias. The first step is to teach children about the historic nature of gender inequality (e.g., laws and practices that rendered women second class citizens) and the legacy of power imbalances (e.g., how gender roles and beliefs about gender created

hierarchical relations) between men and women (Pahlke et al., 2010). Children should be educated about gender stereotypes, their corresponding belief systems (e.g., gender essentialism and zero-sum beliefs), and how they intentionally and unintentionally advantage men and disadvantage women. Otherwise, if pedagogy does not challenge children's beliefs that women are not as competent as men, they will likely express them to justify stereotypes and incidences of sexism (Jost et al., 2004). For example, elementary school students are aware that there have been no women presidents, but two thirds of elementary students state the reason for women's absence is because women are "unqualified" (Bigler et al., 2008), suggesting that students do not understand the historic nature of gender inequities and biases.

Lessons about gender discrimination should be connected to racial discrimination to teach students about the existence and repercussions of gendered racism, which is the intersection of experiencing racism and sexism (Essed, 1991). Ethnic-racial minority women face bias as women, as ethnic-racial minorities, and specifically as women from ethnic-racial minoritized groups (Dickens et al., 2021). Structural obstacles like gendered racism have been found to limit Black girls' access to higher level mathematics courses (Oakes, 1990, 2005) and opportunity to learn in mathematics classrooms (Rist, 2000).

These lessons are also important for White and Asian boys, so they do not continuously receive explicit and implicit messages throughout childhood about White and Asian men's superior status and competence. Finally, students should be taught about the inaccuracy of the gender binary, which refers to the belief that there are only two types of fundamentally distinct humans: men and women (Hyde et al., 2019). Because of the persistent cultural belief in the gender binary, those who do not identify as men or women experience bias that result in marginalization and adverse outcomes. Understanding sociohistorical circumstances is essential for dismantling social dominance and system justification motives that result in hierarchy-enhancing belief systems that elevate and maintain the dominance of White men.

Boys and girls should also be taught to challenge incidences of sexism (Lamb et al., 2009). Lamb et al. (2009) taught children about common types of sexist remarks (e.g., benevolent forms of sexist remarks such as "girls are gentle") and responses to each type of remark, then asked children to perform these interactions. During a follow-up, children who learned retorts to sexist comments were more likely than students who solely learned about peer experiences with sexism to challenge peers' sexist comments (Lamb et al., 2009). To understand why benevolent sexism is problematic, teachers can discuss the origin and use of benevolent sexism (to limit women's social position to "caretaker"), otherwise individuals typically view benevolently sexist treatment as flattering or ambiguous (e.g., a male peer asking female students if they need extra help on a STEM homework assignment). Counseling psychology research indicates that when teachers

establish classrooms with zero-tolerance for sexism, it shifts the norms among students to be more egalitarian and inclusive (Espelage & Poteat, 2012).

Another way to teach about gender bias in STEM classrooms is to change the physical environment to be more inclusive and less traditionally masculine to signal to girls and ethnic–racial minority students that their identities are valued and safe (Davis et al., 2005; Johnson et al., 2019). Masculine objects cue that STEM is associated with men and masculinity. For example, replacing a Star Trek poster with a nature poster increases women’s belonging, and such change in the learning environment does not negatively affect men’s interest in STEM (Cheryan et al., 2009). In line with research elucidating the importance of exposure to in-group exemplars, students also benefit from images that display female scientists (Dasgupta, 2011). Not only will visuals of female STEM experts help change the STEM prototype from White or Asian men to be compatible with girls’ identities, it may also help boys develop more gender-STEM egalitarian beliefs. For example, research indicates that mixed-gender STEM extracurricular programs reduce gender bias among boys when they are exposed to positive information about female scientists (Stake, 2003). Similarly, longitudinal analyses of high school boys demonstrate decreases in stereotype endorsement when assigned to a female teacher (Rieggle-Crumb et al., 2017; Sansone, 2019). An increase in diverse racial representation is critical for increasing ethnic–racial minority girls’ belonging in STEM (Johnson et al., 2019; Pietri et al., 2018). Given their experience with gendered racism in the STEM classroom, Black girls may have even greater feelings of isolation and lower levels of belonging (Joseph et al., 2017), as well as an acute experience of token representation (Dickens et al., 2021), relative to White girls. Since girls and boys are typically exposed to images of White male STEM professionals in the media (Steinke & Tavarez, 2018) and science textbooks (Bazler & Simonis, 1991; Lawlor & Niiler, 2020), the in-classroom presence of diverse scientists can help balance out the underrepresentation children typically observe throughout development.

Intergroup cooperation and collaboration. Drawing on interdisciplinary evidence, positive educational climates characterized by cooperation close achievement gaps between URG and non-URG students in STEM, because they provide dignity, collaboration, and support (Theobald et al., 2020). To foster intergroup cooperation and collaboration, teachers should implement mixed-gender, cooperative learning groups in STEM domains throughout K-12 (Leaper, 2015). Teachers can systematically assign roles to boys and girls to ensure that students do not automatically adopt traditional gender roles where boys take on assertive leadership positions and women function as passive supporters. Engaging with peers on relevant material improves performance, retention, and critical thinking (Kudish et al., 2016; Stefanou, & Salisbury-Glennon, 2002). However, boys tend to be more assertive during STEM-based discussions (Leman et al., 2016), so

teachers should systematically call on boys and girls and communicate the importance of diverse opinions for scientific discussion. Collaborative workgroups help boys and girls develop a common identity as they work toward common goals (Stake & Mares, 2001). The more boys and girls engage in cooperative tasks where they rely on each other to accomplish shared goals, the more they will foster shared identities as “STEM students.” STEM classes throughout K-12 education should incorporate more positive intergroup interactions by allowing peers to form meaningful relationships with one another through collaborative discussions, hands-on activities, and group-based homework projects.

Implementing adaptive active learning and growth mindset strategies. A concern in STEM education in the United States is that students typically report a relative dislike of STEM material by high school (Chen & Soldner, 2013) and these attitudes appear to vary by ethnicity–race and gender (Riegle-Crumb et al., 2011). This suggests that STEM material taught in traditional classroom settings can be more engaging to increase interest in children. Historically, most K-12 students in the United States learn STEM material via traditional, passive classroom settings (Wise, 1996), but cross-discipline evidence indicates that active learning is more beneficial, including in STEM (Ishiyama, 2013; Freeman et al., 2014; Schroeder et al., 2007). Active learning is rooted in constructivist theories of learning that position the learner in control of their own knowledge acquisition, compared to the traditional teacher–student transmission of knowledge referred to as “teaching by telling” (Smith et al., 1997). Examples of some engaging active learning strategies in STEM that can increase engagement among girls are video games (Van Eck, 2006), game design (Siann et al., 1990; Van Eck, 2006), and a robotics curriculum for elementary students (Sullivan & Bers, 2019). Active learning also involves more basic learning processes such as scientific discussions, which stimulate expert-like thinking (Hammer, 1994; Otero & Gray, 2008).

Although the evidence for active over passive learning effects on positive educational outcomes is overwhelming (for a meta-analysis, see Freeman et al., 2014), developing active learning strategies can be stressful and anxiety inducing for students because they require problem-solving and experimentation (Iran-Nejad, 1990; Ishiyama, 2013). This is compounded by the fact that learning STEM material is already anxiety-inducing for most children in the United States (Beilock et al., 2010; Beilock & Willingham, 2014), which can create even more threatening educational environments for girls and exacerbate gender differences in STEM outcomes (Sublett & Plasman, 2017). Thus, incorporating active learning in the classroom is a delicate process that requires guidance, monitoring, and feedback from teachers. Teachers guide students through active learning by teaching techniques to regulate physiological arousal, attention, and effort, while

encouraging students to construct their own conceptual understanding of tasks and constructs (Bell & Kozlowski, 2008).

One effective way to combat STEM anxiety and the impact of stereotypes is by teaching growth mindset strategies, which argue that intelligence is something that is developed over time through effort instead of viewing intelligence as innate and unchangeable (Dweck, 2006, 2015, 2016). For example, teachers can teach students about neuroplasticity (i.e., how the brain is physically changed through learning and effort), which increases motivation and achievement, especially among marginalized students (Sarrasin et al., 2018). Growth mindsets are particularly important for female students since teachers typically associate boys and men with more innate ability and STEM talent (Degol et al., 2018; Huang et al., 2019). When girls believe intelligence is fixed and that girls lack STEM competence, they suffer from weak self-efficacy, which reduces persistence and effort on challenging tasks (Pajares, 2005). Moreover, a feedback loop can emerge such that when girls give up on challenging STEM tasks, it confirms their pre-existing beliefs about lacking innate STEM talent (Pajares, 1996). Fortunately, growth mindsets break this negatively reinforcing cycle by affirming that ability is developed through effort (Degol et al., 2018; Huang et al., 2019). Finally, it is important to not only teach students these mindsets, but for teachers to personally adopt growth mindsets because it impacts the treatment of students and their corresponding academic success (Kraker-Pauw et al., 2017; Smith et al., 2018).

Students can be taught to interpret physiological arousal as a sign of a challenge that requires extra effort, instead of threatening that results in avoidance motivation (Blascovich & Mendes, 2010; Mattarella-Micke et al., 2011). Relatedly, students should be taught that STEM learning is disfluent, which refers to a learning process that often includes experiences of failures and struggles. One effective way to communicate these lessons to students is to teach about the failures and struggles of famous scientists, which improves STEM learning especially for low-performing students (Lin-Siegler et al., 2016). Expressive writing prior to completing a math test reduces math anxiety and improves performance, especially among highly anxious students (Park et al., 2014). This type of task can help reduce intrusive and ruminative thoughts associated with anxiety that usurp cognitive resources (Park et al., 2014).

Teachers and parents should also avoid providing too much assistance to students (especially girls) who are struggling with learning STEM material. Higher frequency of homework help from parents is associated with a long-term increase in math anxiety and reduced math learning (Maloney et al., 2015). Extra assistance signals that the student lacks ability, and also diminishes the development of problem-solving skills. Therefore, when students are struggling, teachers and parents can provide support via emphasizing growth mindsets and helping the student reappraise their arousal to help them expend more effort and persist longer.

Reframing STEM as inclusive. Associating STEM with communal goals and values boosts interest and reduces gender (and racial) gaps in STEM outcomes among K-12 students (Casad et al., 2018; Hughes et al., 2020). STEM material in traditional classrooms is often taught through abstract concepts, which makes it difficult for students to see a connection between STEM and their personal life (Stone & Lewis, 2012). Teachers and parents can emphasize how STEM careers provide communal goal affordances such as helping people through innovation including conservation efforts and advances in medicine. Communal goals can also be achieved in STEM fields (and classrooms) through scientific collaboration and teamwork to solve problems. Emphasizing the communal or altruistic aspects of STEM can help stimulate STEM interest in girls because they place more value on communal than dominance goals (Diekmann et al., 2011). Reiterating that STEM is composed of communal behaviors and goals demonstrates that STEM is not exclusively a masculine domain characterized by needs for dominance and individual achievement. Thus, detailing communal goal affordances may reduce stereotype endorsement among all children and foster more interest among girls.

Near-peer mentorship. An emerging area of research in STEM emphasizes the role of relationships with near-peer mentors, which refers to a mentor slightly more advanced in their educational trajectory than the mentee (Dennehy & Dasgupta, 2017; Kuchynka, Gates, & Rivera, 2020). Near-peer mentoring helps mentees develop STEM-based skills (Quitadamo et al., 2009), promotes STEM interest (Wilson, & Grigorian, 2019), and increases STEM retention (Watson & Mazur, 2013). Though much of this research focuses on college-age near-peer relationships, preliminary research with high school students suggests that near-peer mentoring can have strong STEM-related psychological and cognitive benefits (Kuchynka et al., 2021; Tenenbaum et al., 2014). For example, near-peer mentors can teach students about their personal experiences overcoming struggles with STEM material and function as friends and confidants for mentees. Near-peer mentors can serve as a STEM role model that the mentee can realistically look up to, and, in turn, increase a mentee's sense of belonging in STEM. Forming relationships with near-peer mentors can be especially important for marginalized students because they often feel isolated or excluded from STEM domains (Espinoza, 2011; Dennehy & Dasgupta, 2017). Providing boys with a girl near-peer mentor may help them develop more gender egalitarian views of STEM.

Mentors also experience benefits from near-peer relationships such as increased belonging, self-efficacy, and STEM identity (Trujillo et al., 2015). Mentoring allows students to take on an active role as a STEM role model where they transmit STEM norms and values to their mentees. Therefore, K-12 school systems can create scalable programs where more advanced students mentor students a grade or two below them (e.g., a high school senior mentoring a high

school sophomore or a high school student mentoring a middle school student). Students can be incentivized (e.g., course grade, extra credit, volunteer hours) to join near-peer programs across grade levels.

Shifting evaluation metrics. Current gatekeeping and evaluation metrics in STEM, namely, standardized exams favor White men and disadvantage their ethnic–racial minority and women counterparts (Diele-Viegas et al., 2021). Alternative metrics can be used to evaluate STEM-based learning across K-12 including stealth assessments, which refers to unobtrusively collecting performance data (Georgiadis et al., 2020). For example, student performance can be tracked by playing online games, and these types of assessments demonstrate robust success for measuring student performance across time (Georgiadis et al., 2020; Shute et al., 2021). The unobtrusive nature of stealth assessments allows students to learn STEM in fun, low-stakes environments that do not cue gender stereotypes. Stealth assessments may also be superior to standardized testing because it tracks how quickly students master skills over time.

School systems can also use multiple assessments instead of relying exclusively on standardized tests. For example, they can include measures of social psychological skillsets since academic performance is not the sole (or even the strongest) predictor of academic success (Jackson et al., 2020). Social psychological skills refer to motivation, empathy, problem-solving, adaptability, and group activities, which are closely tied to positive educational outcomes (Dweck, 2006; Duckworth et al., 2007). To illustrate, Chicago-based high school students' socioemotional skills contributes to positive long-term impacts (e.g., college persistence) more than student test scores (Jackson et al., 2020). In sum, relying on standardized test scores as the sole metric for long-term student success creates an incomplete and often times inaccurate picture for who belongs and succeeds in STEM (Jackson et al., 2020; Leonard & Jiang, 1999).

Caveats and considerations. There are some potential roadblocks to consider when implementing the above educational recommendations in K-12 STEM classrooms. For example, if teachers do not personally endorse growth mindsets, growth mindset strategies will not be effective for students (Yeager & Dweck, 2020). Thus, teachers need to “buy in” to the educational recommendations. To achieve this, teachers can be taught the empirical evidence about pervasive gender inequities in STEM and effective strategies including growth mindsets, active learning, and inclusive classrooms. These lessons should be incorporated in teacher training programs across the United States (see “Policy Recommendations” for more details).

Many K-12 teachers across the United States have classroom sizes with over 25 students (Taie & Goldring, 2020) making it difficult to implement educational recommendations such as cultivating relational classrooms with active learning

components. Applying lessons learned from college STEM outreach programs, teachers and school districts should focus on small-group interactions to create cooperative and collaborative STEM environments that foster meaningful relationships (Kuchynka et al., 2019). That is, one way to address these high student-teacher ratios is to develop small-group interactions with about six students per group (Kuchynka et al., 2019). Furthermore, school districts can also address large classroom sizes via the implementation of near-peer mentorship programs, because near-peer mentors can help lead small-group interactions and activities.

Policy Recommendations

Drawing on the seven aforementioned potential solutions for improving K-12 STEM learning environments, we propose three overarching policy recommendations. The following policy recommendations will support the ability for teachers and school districts to adopt each educational recommendation, which are designed to improve gender imbalances by cultivating adaptive STEM learning environments. For example, teachers will not be able to effectively incorporate empirically supported active learning techniques and relational classrooms if they lack resources, are primarily focused on preparing students for standardized testing, and lack understanding of systemic gender and racial biases.

Teacher autonomy, training, and representation. This review presents many contextual and individualistic approaches to improve STEM classrooms that teachers would be responsible for implementing. At the policy level, this will require bringing more autonomy and control back to teachers and local school districts instead of applying standardized school curricula and accountability metrics (e.g., standardized testing) at the federal and state levels. Allowing teachers more instructional flexibility and reducing pressure for meeting federal- and state-level standardized performance metrics should allow for more active as opposed to passive in-class learning. Alleviating pressure placed on teachers for meeting standardized testing requirements will also improve teacher working conditions (McNeill, 2000), which are a central reason for high teacher turnover rates (Hanushek, Kain, & Rivkin, 2004).

The current standardization of public school education in the United States applies the same practices to all students when empirical evidence indicates that individual learning styles, resources, and socioemotional development varies a great deal between students (Alonso-Martín et al., 2021). To help teachers address unique student needs, training programs can be implemented to help teachers design relational classrooms, promote gender egalitarianism, and learn effective ways to teach active learning. Federal initiatives also incentivize school districts to compete for federal funds by comparing standardized test scores (e.g., see Obama's "Race to the Top" initiative, obamawhitehouse.archives.gov).

Competing for federal funds and holding teachers accountable via standardized testing can create even more competitive in-class atmospheres, which typically favor school districts with more resources and personnel and disadvantage low-income, racial-minority serving institutions (Bhattacharyya, Junot, & Clark, 2013). In 2017, a federal bill was introduced to reduce the frequency of standardized testing in K-12 public schooling (see congressional bill H.R.1601). In accordance with this bill, teachers need the autonomy and control to be able to tailor learning environments to individuals and rely less on standardized testing to understand their students' needs.

Finally, implementing the educational recommendations will require state-level accreditation bodies to re-evaluate teacher training and consider the empirical lessons from the literatures on relational classrooms, active learning, education on gender inequities, and how to reframe STEM to be more inclusive for underrepresented students. Teachers can be trained on how to incorporate the educational recommendations via online training modules (see McCombs, 2010). Relatedly, funding should be allocated to improve the diversity of STEM teachers in K-12 school districts. As described in the educational recommendations section, observing diverse STEM representation is key for students to develop egalitarian STEM beliefs. Therefore, federal, state, and local funding agencies should focus on training and hiring more STEM teachers from underrepresented groups.

Re-evaluate standardized testing. To further understand student and teacher needs during K-12, the second policy recommendation is to create a committee at the federal and state levels to re-evaluate the efficacy of standardized tests. As described earlier, the central focus on standardized testing during K-12 creates competitive environments that activates cultural stereotypes, masks the underlying needs of students, and skews the perception of who can and cannot succeed in STEM. The average student in the United States takes 112 standardized tests during K-12, and students in the United States are consistently outperformed by students in countries that average only three standardized tests during primary and secondary schooling (Hart et al., 2015). Therefore, a select committee of educators, researchers, and policymakers can address questions such as: how valid are standardized tests at evaluating student performance, as well as long-term persistence and success in STEM training and professions?; what are the most effective metrics at predicting long-term success in STEM?; should new and emerging metrics such as stealth assessments and socioemotional skills (see above review) be adopted?; and how much standardized testing is sufficient for evaluating student achievement and progress throughout K-12?

Reallocate and increase federal and state funding. The final policy recommendation is to reallocate and substantially increase federal and state funding for

public K-12 schools. It is difficult to curate adaptive learning environments when teachers are underpaid or inexperienced, teacher-to-student ratios are high, and schools lack resources (Hanushek et al., 1999; Blatchford et al., 2008). To illustrate, teachers experience strong and persistent financial anxiety in the United States due to their relatively low salaries, which directly impacts student performance (Hanushek et al., 1999). Larger classroom sizes result in less classroom engagement, and this effect is especially pronounced among low-achieving students (Blatchford et al., 2008). Relatedly, school budget cuts impact student performance, because it decreases the quality of education (Freelon et al., 2012). The increase in STEM outreach efforts, namely, interventions, funded by federal agencies has demonstrated the robust success of isolated STEM programs for improving STEM outcomes among girls and ethnic-racial minority students (Ashley et al., 2017; Clewell et al., 2005; Kuchynka et al., 2020; van den Hurk et al., 2019). Therefore, these funding initiatives need to be expanded outside of STEM interventions to all K-12 public school systems. Surely, we are not the first to propose increasing educational budgets for K-12 public schools to improve STEM education (see congressional bills S.1565, H.R.2027, and H.R.204). We underscore the need for greater funding initiatives because STEM education across K-12 in the United States requires more innovation to improve gender (and racial) inequities in STEM and to increase positive STEM learning experiences for all students.

Future Directions

A disproportionate amount of research conducted on STEM gender representation overly targets college students and the higher education context (Blackburn, 2017; Bloodhart et al., 2020) relative to K-12 student experiences with STEM. For example, most research on the negative impact of lack of diverse representation in STEM textbooks is at the college level (Block et al., 2019; Shapiro & Williams, 2012; Spencer et al., 2016). Greater empirical research on K-12 STEM educational climates including experiences with bias, intergroup and intragroup interactions, and intersecting identities among K-12 students is required. Similarly, the literature is virtually silent on gender inclusive identities (e.g., nonbinary) in STEM (for research on LGBTQ individuals in STEM, see Freeman, 2018). Future research should examine the experiences of nonbinary students throughout K-12 to evaluate their unique needs in STEM learning environments.

Identifying specific K-12 junctures for each educational recommendation to be implemented is another avenue for future research. Providing specific guidelines on grade-level implementation is beyond the scope of this review (for a review, see Kuchynka et al., 2020). We recommend incorporating each educational recommendation early during K-12 to provide positive STEM learning environments that may yield compounding positive effects over time. However, this is an

empirical issue that should be tested by longitudinally evaluating the efficacy of each educational recommendation incorporated across K-12 classrooms.

Conclusion

Increases in STEM outreach efforts over the last several decades (Ashley et al., 2017; Clewell et al., 2005; Kuchynka et al., 2020; van den Hurk et al., 2019), coupled with recent cross-national research findings that indicate girls are less likely to pursue STEM careers in more gender equal countries (Stoet & Geary, 2018), may lead people to conclude that girls may be “naturally” uninterested in STEM. Because the United States is relatively high in gender equality, more attention needs to be given to boys’ and men’s relatively strong resistance manifested in their ideologies and defense of their relatively high status in STEM. Thus, STEM learning environments need to be carefully curated so students are not constrained to traditional gender roles and behaviors, which result in unequal intergroup dynamics. Fortunately, there are many empirically based solutions including equitable socialization practices, cooperative and egalitarian classroom dynamics, guidance during active learning, reframing STEM as inclusive, and near-peer mentorship programs. To implement these strategies, it is critical to shift the focus from pedagogy strongly rooted in standardized testing in STEM K-12 to more adaptive forms of learning that can stimulate interest in STEM. Improving gender imbalances in K-12 STEM involves boys and men participation in fostering positive STEM climates. By implementing the aforementioned strategies and supporting them with funded policies at the state and federal levels, all students in the United States will benefit from being immersed in productive, inclusive, and collaborative STEM environments (Thapa et al., 2012).

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