Gender Bias in Adolescence: Barriers to Girls in STEM and Initiatives to Overcome It

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In the 1970s, as women began to be admitted into universities in large numbers, educators, policymakers, and advocates began actively promoting their involvement in technical fields to close the gap between the genders in both academics and the workforce. In 1970, women made up 38% of workers in the US with only 8% being in STEM areas (Martinez and Christnacht, 2021). Efforts were made to increase these numbers, many fueled by the Second Wave of the women's movement, which was a social and political movement focusing on issues of gender equality, spanning the 1960s and 1970s. One such effort was the enactment of Title IX of the Education Amendments of 1972. Since its passage, federal agencies and educational institutions, such as the U.S. Department of Education and National Academies of Sciences, Engineering, and Medicine, have worked to enforce equal opportunities in STEM education, sexual harassment and discrimination policies, and address other inequalities (Title IX at 50, 2022). In the following years, organizations and institutions implemented bias training programs, put into place work-family support policies, and encouraged gender-inclusive leadership, all showing evidence of increasing women's representation in STEM (Moss-Racusin et al., 2021). As a result, the participation rates for women in the workforce mentioned earlier increased to 48% and 27% respectively in 2019 (Martinez and Christnacht, 2021).

However, despite increasing opportunities for women in STEM fields, the desired rates of inclusion and interest have not, in fact, met our expectations. The increase in women working in engineering occupations has been slight and numbers have decreased for women holding computer occupations. Additionally, initial efforts to diversify the workforce often failed to "generate lasting organizational change" and there continues to be a lack of sustainable representation in STEM fields (Moss-Racusin et al., 2021). The antagonist to our ideal STEM

environment is the ever-present bias toward gender, which manifests a troubling paradox: “while STEM interest is rising, girls’ confidence in their STEM abilities is dropping” (Inc. (ROX), R. O. eXperiences, 2024).

As a woman pursuing a future in STEM myself, I have been a participant in initiatives to engage girls and women in technical areas, as I co-created and co-lead an organization called Mentoring Girls in Computing (MGIC), with the mission to foster positive relationships among girls at a Charlottesville middle school. Through this club, I have observed specific aspects that make the initiative successful and yield encouraging feedback from our participants. MGIC lasts multiple school years, connects middle schoolers with women student mentors, and utilizes active learning to ensure knowledge retention. Thus, this experience left me wondering if these features are common aspects in forming and sustaining an interest in STEM topics for young girls. To understand the specific factors affecting female participation in STEM, I will conduct a meta-review and analyze interviews to answer the following question: how does gender bias in adolescence impact the participation of women in technological and engineering fields, and what factors play a role in mitigating the barriers that discourage girls from pursuing futures in STEM?

Methods & theoretical framework

The purpose of the meta-review is to gain a solid understanding of what professionals do and do not know about gender bias and disparity in STEM fields. It is also to see whether there is a consensus across papers or if there are differing explanations for the gender bias experienced in adolescents. To collect data for the meta-review, I used research platforms like Elicit and Google Scholar. To ensure that search results in these platforms returned papers relevant to my research

topic, I used my research question as well as requests that were tailored towards more specific aspects of my investigation. I chose papers not only based on their content, but also how recently they were published and how often they were cited. The topics of these papers vary from general background on what gender bias is and what it can look like in adolescents to the analysis of interventions conducted to alleviate its effects, and papers yield both quantitative and qualitative results.

For the secondary interviews and personal accounts, I aim to determine the opinions on gender bias directly from those who have experienced it, investigating what factors encouraged or discouraged the pursuit of a future in STEM. The first category explored was women who have played a significant role in STEM fields, such as those that have earned recognition or have furthered research in their studies. The main form of data on factors that affected these women were interviews conducted by reputable sources, such as Nobel Prize or STEM institutions. The interviews vary in length and what questions are asked, as they are not all focused on how they broke into their respective fields. However, a common element in the sources were questions that focused on the development of their passion, impactful role models, and other formative experiences. To begin the collection of data from personal accounts, I first researched prominent women in STEM who hold a position of honor in their field, which ranged from Artificial Intelligence to Biomedical Engineering. These women are likely to be sought out for interviews on their work and accomplishments, as many such women I found for my research had received a Nobel Prize and conducted an interview with them.

Next, I looked for interviews with those that do not necessarily have acclimation and recognition in their fields, but who hold jobs in them and study their topics, nonetheless. Once again, I used Google to search for such interviews, which were often carried out by companies

interviewing their female employees, or by young girls and women looking for insight into the female experience in STEM. I used Elicit to search for peer-reviewed papers that interviewed women that fit such a description, tailoring my research question to deal with interviews or personal accounts addressing barriers to women in STEM and causes of gender bias. This data was much more quantitative than the other sources previously described. One paper that was of particular interest conducted 34 in-depth qualitative interviews with women who left their university STEM degrees and analyzed the findings.

As every girl has their own personal experiences that affect how they respond to interventions and influences, it is insufficient to address gender bias without considering racial and socioeconomic disparities. American academic Patricia Hill Collins states that "solving social problems within a given local, regional, national, or global context requires intersectional analyses" (Collins, 2019, p. 694). For example, case studies have found that Latina women in computer science programs have struggled with the cultural expectation of family obligations, thus limiting their participation in certain activities (Ndubuisi & Amaka, 2024). This implies that tailoring interventions to specific demographic needs will enhance their effectiveness. To give attention to the intersectionality of gender bias, I ensure that the personal anecdotes I review come from women with diverse backgrounds, so that accurate comparisons can be made.

Current Understanding of STEM Gender Bias in Adolescence

Gender bias emerges in early life, influencing children as young as 5-7 years old (Lazarides et al., 2023). My research confirms that harmful stereotypes are reinforced through social influences such as parents, teachers, and friends. A study examining longitudinal data from a sample of adolescent youths found that girls exposed to higher percentages of male peers

endorsing gender stereotypes are less likely to pursue STEM careers, while those exposed to female peers with high confidence in their technological and scientific abilities are more likely to express interest in STEM areas (Riegle-Crumb & Morton, 2017). Furthermore, a self-report survey across high school girls interested in STEM careers, women in STEM undergraduate programs, and women in STEM doctoral programs found that 61% of participants experienced gender bias in STEM fields, with male peers being the most common source (Robnett, 2016). Teachers and parents also reinforce or challenge these beliefs and inequality in the classroom, emphasizing the importance of local classroom environments during formative adolescence in shaping STEM trajectories.

These stereotypes contribute to lower self-efficacy for girls in STEM subjects. Adolescents perceive boys as more skilled in engineering and technology, often seeking male peers for help despite equal abilities, thus reinforcing stereotypes (McGuire et al., 2022). Similarly, higher perceived gender bias correlate with a lower STEM self-concept, with European Americans having higher STEM self-concepts than those of other ethnic backgrounds (Robnett, 2016). Thus, the implication arises that the intersection of different biases can affect marginalized groups more, or in different ways, than others. Importantly, though boys were shown to have higher motivation in math and science, this did not reflect actual performance, reinforcing the idea that confidence, rather than capability, is a primary barrier for girls in STEM (Lazarides et al., 2023).

When it comes to increasing the involvement of girls in STEM fields and sustaining representation, maintaining STEM interest over time remains a significant challenge. Gender disparities in STEM aspirations widen as students progress through school, with girls switching interests away from STEM at higher rates than boys (Saw et al., 2018). Furthermore, “compared

with White higher SES boys, girls from Black, Hispanic, Asian, and multiracial groups, regardless of their SES, had significantly lower rates of […] indicators of STEM aspirations in high school" (Saw et al., 2018, p. 527). Thus, initiatives targeting these disparities have been implemented, with effective ones emphasizing the development of STEM identity over long-term and repeated participation (Prieto-Rodriguez et al., 2020). Additionally, highlighting the practical applications of STEM subjects is a particularly effective strategy for girls and tailoring STEM curricula to include topics that appeal to both genders can increase interest and engagement (Lazarides et al., 2023). To address both motivational and structural barriers, interventions should focus on "doubly disadvantaged" students, such as girls from underrepresented minorities or low-income backgrounds.

Evaluating Intervention Programs: Challenges and Promising Practices

Through my research, I have found examples of initiatives that prove the aforementioned aspects are crucial in making positive headway. The University of Memphis' Girls Experiencing Evolution (GEE) program exemplifies successful intervention strategies, incorporating hands-on challenges, mentorship, exposure to female role model, and training for parents and teachers. Notably, its shift from being a week-long session to a series of 20-hour intensive sessions improved retention and confidence and interest among participants (Ivey & Palazolo, 2011). To further emphasize the importance of long-term initiatives, a study in Knoxville, TN found that short-term, voluntary STEM enrichment programs offered to middle school students did not significantly increase the likelihood of girls pursuing STEM in high school and college, as only 38.9% of girls indicated the intention of doing so (Stanberry et al., 2021). This underscores the need for sustained engagement rather than temporary exposure. Conclusions for this study were

drawn with surveys capturing students' attitudes towards STEM fields and gauging students' future intentions for STEM subjects.

However, when analyzing the effectiveness of interventions, defining and measuring intervention success remains inconsistent. While underrepresentation in STEM has been widely recognized, a standardized, universally effective interventional model has yet to be established. Given the varying experiences of girls in STEM, tailoring interventions to specific demographic needs will enhance effectiveness and address racial and socioeconomic disparities. With that being said, rather than the fact that there is not a recognizable format for interventions, I am intrigued by the inconsistencies with the determination of initiative effectiveness and seeming lack of motivation to make the effort to collect data on the interventions. A consensus on the characteristics and goals of initiatives proven to be effective have yet to be derived, due to "little empirical evidence" (Prieto-Rodriquez et al., 2020, p. 1146) and "the heterogeneity of these studies" (p. 1154). The program GEE stated that "program assessment is crucial to achieving significant positive impact" (Ivey & Palazolo, 2011).

Based on my analysis of peer-reviewed paper discussing the effects of gender bias, I argue that it is key to promote early exposure to STEM for young girls through mentorship programs and tailored initiatives, as peer support can play a part in canceling out the negative effects of bias (Robnett, 2016). Gender bias in adolescence significantly discourages girls from pursuing STEM careers, but well-structured academic and personal initiatives can mitigate these barriers if they focus on long-term engagement, identity development, and intersectional challenges. If young girls participate in long-term, active learning programs where they are exposed to positive role-models, I expect the probability of them taking an interest in STEM topics and maintaining

that interest to increase. Further studies should examine the long-term impact of STEM initiatives and the impact of mentorship on the creation of a STEM identity.

Insights from Interviews: Women's Voices and Experiences

To examine the nuanced experiences and persistent challenges faced by girls in STEM, I conducted a thorough analysis of interviews with individuals who hold positions in STEM fields. The first set of interviews were conducted by a company that provides virtual STEM teaching assistants to look inward at the experience of their female colleagues. The three women at the international company who were interviewed come from different backgrounds and cultures, representing the Netherlands, Mexico, and Bangladesh. The article emphasizes that in early childhood, we are influenced by our parents, teachers, and the media for what we want to do. The testimonies touch on factors such as role models, self-confidence, and lack of representation, with one interviewee stating that her father was a role model for her growing up and sparked her interest in STEM, encouraging her to pursue her interests in physics and astrophysics. Questions and responses also focus on what it is like to work as a woman in STEM, revealing a main obstacle to be the underrepresentation of women in STEM classes and jobs.

A student-run publication that provides a platform for sharing diverse perspectives and stories provided a similar collection of interviews that discuss the journeys of interviewees, challenges, and inspirations in STEM fields (The Smoke Signal, 2024). The first question asked was "How did you gain interest in STEM?", revealing a common theme of parent influence and family tradition. Another recurring theme was exposure to STEM topics through clubs or programs, such as robotics clubs, Science Olympiad, and professional programs. In fact, 3 out of 9 answers noted involvement in a robotics club sometime from elementary to high school. To

answer the question “What were some of the challenges you faced as a woman in STEM?”, many of the interviewees attested challenges to different cultures in how girls and boys are raised. Additionally, male-dominated classes and groups were discouraging aspects, with an interviewee noting “sometimes in group projects, it’s a little scary and intimidating to voice opinions”. In a study conducted through self-report surveys, it was found that peer support can play a part in canceling out the negative effects of bias (Robnett, 2016). This statement combined with the findings from these interviews supports ongoing initiatives that encourage mentorship and positive peer support, as peers that enforce harmful stereotypes create a chilly and intimidating environment for girls in STEM.

In response to “If you’ve ever faced uncertainty about whether you belonged in a STEM field, how did you tackle that?” there were some interesting and noteworthy answers. First, one interviewee moved to the US from Romania and perceived that there was an expectation in the states that girls should not be good at math, which was different from where they came from. She stated that, “I felt that in order to belong, I should not be good at math, and that’s when I started to believe that I didn’t want to do science”. This demonstrates that gender bias and stereotypes pushed on girls at a young age are detrimental to their continued interest and belonging in STEM. Another participant also stated that uncertainty is an ongoing problem for them due to imposter syndrome, touching on low STEM self-efficacy as a consequence of gender bias.

When addressing their hopes for the future of women in STEM and advice they have for girls interested in a STEM career, interviewees expressed a desire for an increase in women in higher leadership positions. With this, they emphasized the importance of “safe spaces” for women so that confidence can grow, and stereotypes can be eliminated. One interviewee connected their experiences to a prevalent theme of early exposure, stating that “I was exposed to science in

elementary school…So I think elementary school is a great time for there to be more initiatives for people who identify as women or other minority genders to be introduced into STEM." An overwhelming topic present in the offered advice was women empowerment and the perseverance of interest in STEM topics, highlighting STEM self-concepts and the discouragement of interests in technical and scientific subjects. One specific quote stuck out to me; "I feel like for the computer science club I run for middle school girls, I know that many of them wouldn't have joined if it was not only for girls." The interviewee is implying that mixed gender club would create a domineering experience for young girls and expose them to the perpetration of gender stereotypes. As I myself run a middle school coding club for girls, this drove me to reflect on the experience I am creating for the girls. The participants are given a comfortable space to explore their technical interests, but this might not be the case with future experiences. Thus, moving forward I am determined to not only foster positive relationships between the girls and mentors, but build on their confidence in the topics so that they can advocate for themselves when put in intimidating situations.

The final set of interviews in the first category was conducted by a rising high school junior that was curious about the experiences of women in STEM fields (Teller, 2019). The three women she interviewed primarily gave insight to how women face obstacles in their higher education, as two of the three women discussed the gender bias in grad school and PhD programs. An outlier from previous anecdotes, the third interviewee had a distinctly different experience with STEM, as she attended an all-girls high school, making her unaware that women shied away from STEM classes. A formative experience for her was when a teacher went around the room calling on boys to answer a question but purposely skipping her when she was the only girl and had the correct answer. This shows that the behavior of teachers in the classroom plays a

significant role in carrying out gender bias. When asked about ways that they think we can fix the gender bias problem in STEM, McRae (an interviewee) stated “in middle school, exposing young women to sciences, math, and engineering is really important”, adding to the consensus that gender bias needs to be combatted young.

The next category of interviews explores prominent women in STEM that have completed innovative research and projects in their respective fields. The first interview was conducted by Nobel Prize with Jennifer Doudna, an American biochemist who won the Nobel Prize in 2020 for the development of a method for genome editing (Interview with Jennifer A. Doudna, 2021). Doudna decided to pursue science because she loved math growing up, her father encouraging her to pursue her interests and acting as a key influence. Advice she would give young researchers is to “find supportive mentors who will help you through the tough times, and then just keep going”, highlighting the need for mentors that can help navigate gender bias. When asked about specific advice for young girls interested in science, she said “I think it’s something that as women, we have to…actively put that little voice aside and trust that actually they’re probably better than they think they are.” This demonstrates the imposter syndrome and low self-efficacy that women and girls in STEM often experience.

Maryam Mirzakhani was an Iranian mathematician who was recognized for her work in the dynamics and geometry of Riemann surfaces. In an interview with the Clay Mathematics Institute as a recipient of the Clay Fellowship, Mirzakhani states that she started pursuing mathematics in high school and that her older brother sparked her general interest in science, though her parents were supportive as well. During her education, Mirzakhani had a friend with the same interests who helped her stay motivated towards her goals, speaking to the theme of peer support. Additionally, her high school president was strong-willed and went out of her way

to provide girls with the same opportunities that boys had, providing an example of confident, female role models that advocate for young girls experiencing gender bias.

Across the interviews, there were repeating themes that give insight into the factors that encourage and discourage women from participating in STEM fields. Many women in the interviews cited a parent or family members as role models who encouraged their curiosity in STEM subjects. With the appearance of fathers as role models, it suggests that it is not only women's responsibility to inspire interest in STEM areas and that men can and should be mentors to girls and women. Previous studies have stated that fathers can have a significant influence in their daughters' choice of computing careers (Denner, 2011), and it was compelling to see this play out through personal accounts. Many of the women indicated that they participated in clubs such as robotics, Science Olympiad and other initiatives, coinciding with an early exposure to STEM programs. Additionally, having a strong mentor or supportive teacher seemed to reinforce persistence in STEM. However, common challenges do arise, mainly one being gender stereotypes and bias. Societal expectations and male-dominated STEM programs discouraged girls from excelling in STEM and reinforced self-doubt. Many interviewees stressed the need to introduce STEM in middle school to combat gender bias early and finding strong peer groups, faculty allies, or industry mentors helped women persist in STEM careers.

To see the other side of the story, I utilized interviews from women who ended up in other fields, though they initially held an interest, education, or career in STEM. Questions from 34 interviews with women who decided to leave their STEM degrees focused on motivations for choosing an engineering degree, confidence levels, influence of social environment, and socioeconomic factors (González-Pérez et al., 2022). The following were key reasons women left STEM fields: chilly and hostile environment in classes, workload from an excessively

demanding curriculum, lack of role models, perceived incongruity between the female gender role and STEM roles in society, and the lack of institutional support. Early socialization and gender norms led to a perceived misalignment between internalized communal values and agentic traits. This anticipated struggle made some hesitant to pursue STEM careers, one interviewee stating that she saw engineering as a career that had many professional opportunities but has never seen herself working in the engineering world. Furthermore, adolescent girls who lacked peer support in STEM-related activities were more likely to drop out later, an interviewee stating that "if you are alone, you feel alone, and it is very difficult for you to take it forward." Girls who encountered discouragement from teachers or parents about their STEM abilities were less likely to persist in STEM majors, some even reporting that they were subtly guided toward "softer" sciences or non-STEM careers from an early age.

Finally, though self-efficacy is stated as a possible reason for women dropping out of STEM fields and classes, there were no major differences in self-efficacy perception between women who persisted in engineering and those who dropped out (González-Pérez et al., 2022). A discouraging quote from one woman attests to this, saying "impostor syndrome in a woman's life is inevitable. And more so in a world of men. It's just that it's impossible not to feel inferior." This suggests that external factors may play a bigger role than self-confidence alone, with self-efficacy being essential when girls are young, but new problems emerge when they enter college and their young adult years.

Given the results of the analysis on personal anecdotes from women in and out of STEM, I argue that there are key factors that influence whether a girl will pursue or be discouraged from pursuing a future in STEM. Namely, supportive role models, peer and family encouragement, and participation in STEM programs were common among the personal accounts of women who

are interested in and currently hold a position in a STEM field. Because STEM programs were a recurring theme, I argue that initiatives to mitigate the effects of gender bias play a significant, positive role in addressing the barriers between girls and STEM careers. Since women who left STEM pathways cited a lack of models and perceived incongruity between the female gender role and STEM roles in society, gender bias leads to low self-esteem and a hesitance to consider STEM futures. Thus, effective ways to tackle these problems are institutional and personal support for girls, with the aid of personal initiatives, such as robotics and coding clubs welcoming girls.

Conclusion

By shedding light on the pervasive impact of gender bias during formative years on young girls' participation in STEM fields, the research I conducted reveals key themes and explores the structural and cultural barriers that hinder women's involvement and advancement. Based on personal anecdotes and peer-reviewed research, factors such as supportive role models, peer and family encouragement, and participation in STEM programs are crucial in fostering interest in STEM. Tailored initiatives that promote STEM identity through long-term engagement and intersectional approaches are critical to mitigating barriers that discourage women from following a STEM pathway. Additionally, my research indicates that mentorship, equitable access to opportunities, and peer support are essential to fostering an inclusive STEM environment. Women who leave STEM pathways often cite a lack of representation and societal stereotypes, highlighting the need for institutional and personal support to sustain girls' interest in STEM.

Moving forward, we must rethink our approach to gender equity in STEM by ensuring initiatives are intentional and impactful, rather than symbolic. Programs designed to support women in STEM should follow standards, ensuring they address root causes and take measures to analyze the success of the initiative with empirical data and personal testaments. Additionally, enforcing standards in education and workplace policies can help mitigate gender biases that formed in early developmental years. Emerging discussions around diversity and inclusion, along with shifts in policy and societal attitudes, many influence gender representation in STEM. Thus, future research should build upon these findings by examining the long-term impact of STEM initiatives and mentorship on the development of a STEM identity, incorporating direct interviews with women in STEM to provide deeper insight into their experiences and further refining strategies for meaningful change. We must move beyond surface-level efforts and commit to systemic and institutional reforms that create lasting, equitable opportunities for girls interested in STEM, because without diverse voices, innovation will always fall short of its true potential.

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