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# Turning the Tide for Academic Women in STEM: A Postpandemic Vision for Supporting Female Scientists

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## Abstract

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The “leaky pipeline” of women in science, technology, engineering, and mathematics (STEM), which is especially acute for academic mothers, continues to be problematic as women face continuous cycles of barriers and obstacles to advancing further in their fields. The severity and prevalence of the COVID-19 pandemic both highlighted and exacerbated the unique challenges faced by female graduate students, postdocs, research staff, and principal investigators because of lockdowns, quarantines, school closures, lack of external childcare, and heightened family responsibilities, on top of professional responsibilities. This perspective provides recommendations of specific policies and practices that combat stigmas faced by women in STEM and can help them retain their careers. We discuss actions that can be taken to support women within academic institutions, journals, government/federal centers, university-level departments, and individual research groups. These recommendations are based on prior initiatives that have been successful in having a positive impact on gender equity—a central tenet of our postpandemic vision for the STEM workforce.

## Graphical Abstract

Women in scientific fields continue to face an uphill struggle with under-representation, salary discrepancies, and increased career-related hardships. Despite progress over the past decades, these challenges were significantly aggravated by the COVID-19 pandemic and have accentuated the so-called “leaky pipeline”, a model that depicts how women in science, technology, engineering, and mathematics (STEM) have missed opportunities due to gender bias and existing structural obstacles. These barriers affect all facets of the scientific enterprise, including publishing, hiring, funding, and advancement into more senior positions.[1,2] The consequence is a stagnant gender gap among researchers and faculty, despite significantly increased numbers of women receiving advanced degrees in STEM.[3–5] Broadly speaking, more than 70% of STEM laboratories have male principal

investigators (PIs), and these laboratories are less likely to include female graduate students and postdoctoral trainees.[6] Women are also 10–20% less likely to earn the title of PI compared to male peers.[7,8] On average, startup funds offered to women are ~$500,000 less than those garnered by their equivalently qualified male counterparts.[9] When manuscripts written by women are reviewed by all-male teams of reviewers, their work is less likely to be accepted for publication.[10] “Double-binds”, a term that captures the irreconcilable gender-and race-based oppression faced by women of color—especially women who are Black, Indigenous, and people of color (BIPOC)—poses another set of obstacles to career advancement in STEM fields.[11] When it comes to the fields of physics, engineering, and computer science (PECS), there is an even greater disparity, with a ratio of about 4 men for every 1 woman.[4] Women may avoid studying or exploring careers in PECS in part due to having less confidence in their quantitative skills, prioritizing work–life balance over salary, having superior communication skills, and lacking appropriate preparation. A recent study indicated that closing gender gaps in terms of representation and retention in PECS can help support the success of high-achieving women, but other factors prevent average and low-achieving women from entering and advancing within these fields in comparison to low-achieving men.[4] The study also found that if PECS graduate programs admitted students based solely on academic merit, there would be a higher proportion of female students in these programs.

The inequality in opportunities and advancements that women in STEM and PECS experience tell just one part of the story. Beyond these issues, the difficulties that women face in academia often center around overwhelming and unreasonable expectations to perform at or above the levels of their male counterparts while also adhering to outdated social norms and expectations that they are responsible for the bulk of housework and childcare, even when they can be considered the breadwinners of their families. Female research scientists with children, some of whom are single parents, face consistently unreachable standards. Although they may try to solve this dilemma with late nights and early hours in the lab or office, the stress and adverse health consequences of these patterns far outweigh any potential job-related benefits.[12] Additionally, the culture of academia still regards academics with stay-at-home partners in a better light. Statistics showed that less than 50% of the spouses of male faculty in STEM work full time.[13] This number is a stark contrast with the 90% of male spouses of women faculty in STEM who are employed outside the home.[13]

The effects of these disparities are unequivocal and were clearly illuminated by the COVID-19 crisis. During the first few months of the pandemic, experts gathered significant evidence of gender differences between publication rates of women *versus* men among research reports, preprint servers, and journal submissions.[14] As the pandemic progressed, nearly 20% fewer women were first authors on COVID-19-related papers as compared to papers in previous years in the same journals.[1] This trend extended to senior/corresponding authors as well, with fewer females listed in this position during the pandemic as compared to previous years. There is no doubt that these differences are due to pandemic challenges disproportionately faced by female scientists, particularly early career researchers. A recent report from UNESCO suggests that the time spent on research by women scientists with children five years of age or younger was impacted negatively by ~17% compared to

their non-child-rearing colleagues and compared to their own pre-COVID productivity.[6] Female scientists with multiple dependents experienced even greater setbacks in time spent on research.[6] Not only were there fewer publications from female scientists, but there were also fewer preprints from them compared to male scientists.[8] This phenomenon has been documented in biomedical research in all of the 10 nations with the greatest numbers of researchers, namely, the United States, the United Kingdom, Australia, Canada, China, France, Germany, India, Italy, and Japan.[15] These issues were not generated by the pandemic; rather, pre-existing stresses were exacerbated by the restrictions placed on female graduate students, postdocs, research staff, and PIs due to school closures, lack of external childcare, and increased family responsibilities in the face of unrelenting academic standards and obligations.

These challenges are further compounded by persistent gender and sexual harassment toward women in science, as reported by the National Academies of Sciences, Engineering, and Medicine (NASEM). A 2018 report, which was based upon surveys that were widely distributed across the Pennsylvania State University and University of Texas college systems to assess and to describe different forms of gender harassment and hostility among female STEM undergrad and graduate students, noted that a quarter of engineering students and half of female medical students have experienced “sexist hostility”.[16] This term describes beliefs and behaviors that aim to preserve traditional gender roles through the subordination of women, such as demeaning jokes or comments that belittle women’s intellect or hard work. Sexist hostility creates an environment that makes sexual coercion and assault more likely to occur, further discouraging women from pursuing STEM careers.

Importantly, gender discrimination can continue to persist and to be perpetrated by individuals who do not realize it is happening. Individuals who believe that bias and unfair treatment based on gender do not exist in their field may, in fact, be significant contributors to it.[17] Even in situations where women are broadly represented, they can still encounter problems because of how they are perceived based on their gender. These observations challenge the validity and efficacy of our current methods of training STEM professionals about gender inclusivity.

## RECOMMENDATIONS

As the pandemic continues, even with the wide administration of multiple vaccines to target COVID-19, it will continue to affect the way we live, work, and function in society for years to come. In addition, the mental health toll of stress and isolation will affect a generation of individuals and families.

At this point, almost two years since the start of the pandemic, it is important not only to detail the disparities faced by female scientists, but also to develop and to implement pragmatic solutions that can rectify the gender gap in STEM. Scientific success is gauged through measures of output and productivity, including the number of researchers a PI has trained, the careers of these mentees, the quantity and quality of published papers, the amount of research funding generated, and prestigious honors awarded. Although these are certainly key indicators of academic success, it is at least equally important to analyze

whether these objectives were achieved with a culturally competent lens and through equitable leadership and mentorship.[18] Considering the decades of rules and conventions that have largely failed to prioritize the well-being of women, these solutions must be implemented globally and should include and expand on policies that are holistic and gender-sensitive.

A virtual conference was organized in May 2021 by Mothers in Science (MiS), a nonprofit international organization whose goal is to enhance employment and retention of women in STEM careers. The meeting included 176 participants from 46 countries. Not only did this event highlight the “motherhood penalties” women scientists commonly experience, but it also documented how the COVID-19 pandemic prompted changes that can aid scientists in balancing parenthood and research.[19] Inspired by these changes, we outline four key actions at institutional, nonfederal, and federal levels to address the major pre-existing STEM disparities that have worsened due to the pandemic crisis:

1. Targeted support for female scientists who are mothers, including better childcare options and maternity leave policies;
2. The establishment of institutional advocates for female scientists and the unique issues they face;
3. Individualized pathways and improved mentoring for academic advancement by female scientists; and
4. Improved funding for female scientists through increased grant and publication opportunities providing additional time, supplements, and flexible grant deadlines.

## Support for Female Scientists Who Are Mothers.

Early career women researchers are at a particularly high risk of leaving STEM fields due to childbirth or other family-related events, and over 40% of women faculty leave their academic fields after the birth of their first child.[20] Many of these departures may be due to the added demands of childcare and domestic work, which disproportionately fall on women. As a result, there is a major disparity among faculty by gender that continues along the academic pipeline, an effect amplified by the COVID-19 pandemic. It has been widely reported that female academics with young children struggled during COVID-19 lockdowns to record lectures and to prepare lesson materials, to perform administrative duties, to analyze current or past data, and to be professionally productive as their home and work lives merged. Online teaching is generally more time intensive than in-person instruction because of restricted contact with students, problems with technologies, and a lack of web-based instructional materials that are easy to use.[21]

One major step that should be taken by institutions is to provide greater financial and administrative support for women with young children. Since the onset of the pandemic, only a small minority of institutions have expanded or even provided childcare services, even though this is a crucial aspect of maintaining professional productivity. It is in the best interests of both female scientists with children and the institutions they serve to implement more expansive and accommodating childcare services. For example, the NIH

central resource for grant and funding information has provided flexible, family friendly initiatives for trainees that receive NIH National Research Service Awards (NRSA). This initiative includes paid parental leave for either of the parents for 8 weeks, provided the applicant has the leave preapproved by the training program director, and $2500 per annum for childcare costs from a licensed care provider. Ideally, these policies would be universal for trainees regardless of funding source. Research-intensive institutions should consider awarding adjustable funding to improve the efficiency and stability of researchers with childcare duties, with a focus on promoting BIPOC women.[22] This mechanism could potentially "buy out" graduate student teaching requirements, freeing their time to focus on research. It would also relieve PIs of the financial burden to fund parental leave. The NIH should also consider adding another group in addition to the new investigator (NI) and early stage investigator (ESI) classifications to further support mothers with young children through a one-time funding option with flexible percentile limits.

### Institutional Advocacy for Female Scientists and Students.

At Oregon State University, a seminar supported by the National Science Foundation's ADVANCE program aims to instruct professors and administrators about how they can effect change within their own institutions.[23] This seminar is based on instructing faculty about systems of oppression and intersectionality and how discrimination against women is historically rooted in policies and practices. Faculty and administrator participants have come away with a significantly better understanding of the systemic and historical origins of gender disparities in science, as well as concrete plans for how to change established hierarchies and how to improve the standing of women within their own departments. Data revealed that the seminar led to substantial modifications to institutional structures with the goal of improving the career advancement opportunities of women in academia.[23]

Having easy-to-access advocacy committees at every institution will give female students, staff, and faculty a chance to talk freely about their challenges, and it will give them a voice in catalyzing change. It is essential for these committees to be led by female faculty and to include experienced personnel, student representatives, and senior administrators who can work together in addressing complex gender-related disparities (*e.g.*, unequal pay), improving mentoring frameworks, promoting policies that support academic mothers and women of color, enhancing innovative recruitment efforts, and establishing an institutional culture that is more understanding of the increased stressors faced by women, among other priorities.[24] The empowerment of female advocates will be especially significant in the postpandemic world to address the increased disparity between female scientists and their male counterparts.

These committees must be effective in analyzing and addressing the wide range of biases that women face in STEM fields. For example, implicit bias continues to exist in workplaces, even when women are being hired equally, as was shown by a recent study of managers in traditionally male-occupied fields who consistently recommend higher salaries and gave more positive evaluations to sample employees with male names.[17] One report titled "Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering" advocates for the establishment of an "interinstitution monitoring

organization" to create initiatives for extending the involvement of women in science, engineering, and technology.[13] Furthermore, instances of explicit bias, discrimination, and harassment also must be addressed, as female faculty in academic institutions around the United States continue to report experiencing the resulting negative impacts on career advancement.[25]

### Holistic and Individualized Pathways for Career Advancement.

Normalizing personalized career development for trainees, postdocs, staff, and faculty is of utmost importance. Such practices include case-by-case milestones, more flexible guidelines, and inclusive metrics of success.[26] These components can be supplemented by committee oversight and targeted training for university administrators and PIs (or other mentors) on how to support those with childcare duties.[22] This increased personalization will lead to the more holistic consideration of individuals' personal and professional circumstances in career advancement. These principles must also be extended to consideration of tenure, an area in which women continue to experience a gender gap related to unequal evaluation processes.[27] As of 2013, women held only 38% of tenure or tenure-track positions in the United States, and women of color held only 2% of these types of positions.[28,29] Therefore, even more urgent, targeted approaches are needed to focus on women of color.[29]

For research trainees, discussions about long- and short-term goals between mentors and their mentees who are entering into parenthood can facilitate proactive planning to establish realistic expectations. These conversations can often reveal discrepancies found in institutional paid-leave policies and enable these concerns to be addressed well ahead of actual need, decreasing the cumulative emotional and financial burden upon mentees who start families during their training. It is important for mentors to keep mentees who have recently become parents updated on what is happening in the research group, with collaborators, and within departments—including them in networking events, for example, without expectations related to productivity. Equally critical is assisting mentees in finding support groups related to their individual challenges with raising children while navigating academia.[5]

### Increased Grant and Publication Opportunities with Flexible Deadlines.

At the federal level, although there are many grant opportunities for all scientists irrespective of gender, it has become increasingly challenging for female scientists with childcare duties to meet fixed grant deadlines. Women in this situation may work many nights while neglecting their health or drop out from the grant submission process altogether due to excessive stress. These circumstances are the result of unfair and unequal societal expectations that place extra pressure on women to take on family duties that can easily fill a daily schedule, leaving limited time for grant and manuscript writing. This effect worsens other disparities between the academic life of females and that of their male colleagues. This problem extends further to the differential amounts awarded to PIs on many grants. For example, between 2006 and 2017, across all NIH grant types and institutions, first-time female PIs received nearly $40,000 less as compared to their male counterparts.[30] This disparity extends across multiple types of institutions, with female PIs receiving ~$82,000

less at Big Ten universities, ~$20,000 less at Ivy League Universities, and a median of $41,000 less across the top 50 NIH-funded institutions.[30] These observations require further exploration at the federal level into the systemic issues that may be causing female faculty to receive substantially less funding, and new rules should be implemented to mitigate these effects.

In addition, the federal and state governments should establish extended or flexible grant deadlines depending upon the extraordinary circumstances of applicants, including family responsibilities, childcare, maternity leave, and recovery from illness or trauma. Currently, there are few flexible grant opportunities, and these apply to a small number of scientists and do not fully address the needs of female scientists. It is important for funding agencies to create adaptability in their endowment regulations for grants and to introduce no-cost extensions for grant applications because of the multiyear nature and after-effects of the COVID-19 pandemic.[22] Furthermore, the paperwork overload related to frequent and successive grant applications commonly needed by PIs with additional caregiving roles to continue and to support their research should be reduced. More efficient procedures for submitting varied grant corrections and rebudgeting appeals would help mothers to focus substantially more of their time and energy on advancing their research. Funding agencies also should consider allocating short-term monetary awards to aid academic mothers at different career levels, such as adding an additional category (similar to ESI and NI) for academic mothers to give them a competitive advantage.[5] Funding agencies might consider dedicated RFAs for academic mothers (with a limit of one per mother) or for productive women scientists who have not had any active grants in the past two to three years. Although the details of these proposed classifications and grant opportunities warrant further discussion, particularly around whether they should be available as one-time opportunities for use during times of crisis such as a pandemic, their general utility toward helping female scientists is unquestionable.

In 2018, research scientists used computerized techniques to assess the number of male *versus* female authors posted on greater than ten million publications in academia since 2002 as a way of precisely estimating the gender gap among researchers across scientific disciplines and its rate of change. Given the slow rate of increase in women authors, the researchers concluded that many fields, including physics, computer science, surgery, and mathematics, will not reach gender parity within the next 100 years. This study and others suggest that women being less frequently invited to author manuscripts has contributed to lower publication rates, which is consistent with previously documented gender prejudice from journal editors (*i.e.*, women appear in senior authorship roles—the last-listed author, sole-author, or corresponding author—less often than their male counterparts).[31] In 2020, manuscript submissions from female researchers across multiple disciplines dropped dramatically within the first few weeks of the pandemic, including COVID-19-related studies led by women.[32] Because of the long and tedious process of publishing, this disparity has grown deeper in the aftermath of the pandemic.

Because research publications are important for academic career progression, both scientific societies and publishers can adopt initiatives to increase the representation of women, particularly academic mothers, in the literature, both during and after the COVID-19

pandemic. Recommended measures already in place at certain journals include the promotion and prioritization of submissions from women during peer review, deadline extensions for open access publication waivers to manuscripts authored by those with parental responsibilities, and targeted invitations and incentives for women to serve in editorial positions as a means of amplifying female voices and perspectives.[22,33] Another proposal encourages editorial teams to examine inequalities among gender in terms of authorship, which can help to motivate research teams to pay attention to gender equality in authorship.[31]

Finally, changes to funding systems that benefit academic mothers can also take place through philanthropic organizations. For example, philanthropies and nonprofit funders such as those that are part of the Health Research Alliance (HRA) consortium frequently award hundreds of millions of dollars per year—between 2006 and 2008, nearly $3 billion in HRA non-profit-based grant funding was awarded, and the spending increased 26% over those three years.[34] This potent sector of support can be better utilized to offer new opportunities to female scientists and academic mothers, particularly because these agencies may have fewer hurdles in the application process.

## CONCLUSIONS

The inequities faced by women, and particularly women of color, in scientific fields begin during the formative years of education and persist in unequal training, mentoring, funding, and publishing opportunities—important determinants of success and advancement. There are multiple types of policies and practices that academic institutions, research funders, and publishers can adopt to foster a more supportive environment for female scientists at various career stages. The successful examples highlighted here point in the right direction, and now is the time to make such changes ubiquitous. In examining and analyzing the treatment of female scientists at our own institutions, we have received support along the way from colleagues, department chairs, deans, and journal editors, and we hope this type of support for both the betterment of gender equality in the sciences and highly participatory institutional self-reflection becomes normalized.

Although the benefits of institutional and federal changes are clear, there must also be continued fundamental societal shifts in perceived gender roles to promote more shared responsibility of childcare, domestic work, family support, and emotional labor among working parents, as well as a shift in institutional culture that is consistent with policies that benefit working mothers at distinct phases of their scientific careers. Even before the pandemic, this disparity in expected roles impacted women’s ability to advance in their careers. All too often, the fallacious argument is made that female scientists, along with women in countless other careers from investment banking to telecommunications, fail to advance in their fields because they “make the choice” to prioritize family life. This position fails to consider that the reason this imbalance in female advancement exists is the lack of appropriate childcare and support across most industries, paired with intergenerational inequalities ingrained in modern society. Both of these factors must change for all women to truly access equal opportunities. When women are given supportive resources and tools

to succeed, the STEM workforce is more inclusive and broader in perspective, and science becomes more innovative and transformative.

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