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Jefferson, Felicia A. ; Hora, Matthew T. ; Pickens, Sabrina L. ; et.al.

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The Impact of COVID-19 on Tenure Clocks, the Evaluation of Productivity, and Academic STEMM Career Trajectories

AUTHORS
Felicia A. Jefferson, Ph.D. (1)
Matthew T. Hora (2)
Sabrina L. Pickens (3)
Hal Salzman (4)

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Affiliations: (1) Biology Academic Department, Fort Valley State University, Fort Valley, Georgia; (2) Department of Liberal Arts and Applied Studies, University of Wisconsin–Madison, Madison, Wisconsin; (3) University of Texas Health Science Center, Houston, Texas; (4) E. J. Bloustein School of Planning and Public Policy, J.J. Heldrich Center for Workforce Development, Rutgers University, New Brunswick, New Jersey

Communicating Author:
Felicia A. Jefferson, Ph.D.
Associate Professor, Biology Academic Department, College of Arts and Sciences
Anne Gayles Felton Academic Classroom and Laboratory Building (ACLB)
Room 301
Fort Valley, GA 31030-4313
478-827-3254
jeffersonf@fvsu.edu

INTRODUCTION

This chapter provides insights into the COVID-19 pandemic amplification of long-standing career challenges for women in the STEMM (science, technology, engineering, mathematics, and medicine) academic workforce. In particular, we focus on the ways that institutional policies regarding productivity, advancement, and opportunity can ameliorate the negative impacts of the pandemic on their lives and careers. The findings indicate that the pandemic is having a dramatic impact on their academic work—here considered as the collective research, teaching, and service responsibilities of faculty (tenure and non-tenure-track), academic staff, postdoctoral researchers, and graduate students. The data also suggest there is a differential impact from the overall and widespread shifts to online instruction, the closure of campuses and research labs, hiring freezes, exacerbated by the added stress wrought by lost jobs, childcare, and people's health that are massively disrupting higher education. These disruptions are forcing colleges and universities to re-think the nature of academic productivity and work-life balances in policies governing funding. There are encouraging indications that policies emerging across the postsecondary landscape may minimize the negative impacts of the pandemic on the academic STEMM workforce.

Although overall policy changes may address the impacts broadly, the pandemic is not affecting all populations in the same way: there are more deaths, illnesses, and unemployment evident among low-wage workers in the service, retail, and healthcare sectors, and non-white Black, Indigenous and People of Color (BIPOC) persons, with Black people dying at 2.1 times the rate of white people (Centers for Disease Control, 2020), and racial minorities representing 78 percent of deaths among people under the age of 21 (Bixler et al., 2020). It is important to recognize that the disproportionate impacts of the pandemic on BIPOC populations is the

outcome of policies and socioeconomic structural factors that intersect with racial factors: some of these groups are at higher risk for being low-income, have limited access to healthcare and increased exposure to the virus due to their occupations. Thus, the risk of contracting and dying from COVID-19 is not random but is instead shaped by this intersection of several socioeconomic structural factors and policies that can accumulate and compound an individual's marginalization in society, and during a pandemic, increase the chances that their lives, health, and future prospects are disproportionately vulnerable to the direct and indirect effects of the pandemic.

The idea of "intersectionality" captures this phenomenon—how an individual's opportunities are shaped (and constrained) by overlapping systemic forces and their various identities (e.g., age, race/ethnicity, gender identity)—and provides a useful heuristic or analytic lens for considering the ways that the COVID-19 pandemic has impacted the STEMM academic workforce. Introduced into the popular lexicon by the legal scholar Kimberle Crenshaw (1990), intersectionality has been used to study many topics relevant to STEMM education, including the experiences of women of color in physics and astronomy (Ko et al., 2013), how Black women and girls remain "hidden figures" in STEM fields (Ireland et al., 2018), and how postsecondary institutions can support the success of underrepresented minority (URM) women in STEM fields (Armstrong and Jovanovic, 2017). Given that evidence is mounting that the COVID-19 pandemic is disproportionately impacting the careers of women in academia (e.g., Cardel et al., 2020; Kibbe, 2020; Staniscuaski et al., 2020), an intersectional analysis of the ways that different identities and discriminatory structural features of our educational and economic systems is especially warranted if the field is to identify and support policies and practices that enhance the career prospects of *all* STEMM researchers.

A summary of the evidence about the impacts of the COVID-19 pandemic on STEMM academic careers is presented in this chapter, with a particular focus on how these impacts vary across different identities (e.g., career status, disciplinary affiliation, race/ethnicity, and gender) and structural features (e.g., institution type). To establish the context for this analysis, the impact of the pandemic on the labor market in general and the STEMM job market in particular is first discussed, followed by an in-depth analysis of changing notions of academic productivity and the potential impacts of hiring freezes, budget cuts, and institutional policies developed in response to the pandemic on the prospects of STEMM researchers. In analyzing the impacts of these structural forces on STEMM scholars, the differential impacts on particular identities—especially those of women—are considered using an intersectional perspective. Implications of the findings are then considered for educational policy and practice, with a focus on ways that higher education can best support STEMM scholars with multiple, overlapping identities that place them at higher risk for leaving the profession, so that they can be successful in remaining productive and healthy amidst the global pandemic.

METHODOLOGY FOR THE REVIEW

This analysis is based on a review of recent papers, presentations, and other available documents examining the impacts of COVID-19. First, a search of Google Scholar and PubMed was conducted using combinations of the following search terms: "STEMM," "careers," "pandemic," "intersectionality," and "women." The papers and conference presentations that were identified using these terms were reviewed using the following inclusion criteria: (1) manuscripts are in English, (2) papers and presentations are peer-reviewed, and (3) the content of the manuscripts addresses the impacts of the COVID-19 pandemic on STEMM careers,

institutional responses to the pandemic, and/or the differential impacts of the pandemic on women and/or BIPOC researchers in the STEMM disciplines. The papers and presentations included in the final review were analyzed using content analysis techniques, with research findings and/or STEMM scholars' assessments or conclusions on the topics addressed in the inclusion criterion.

The findings of this review are summarized and then further analyzed using the analytic lens of intersectionality. Additionally, several terms used in this chapter are worth defining given the potential ambiguity related to their interpretation. The important terms used throughout the chapter include:

- **Intersectionality:** The interconnected nature of social categorizations such as race, class, and gender as they apply to a given individual or group, regarded as creating overlapping and interdependent systems of discrimination or disadvantage (Oxford English Dictionary, 2020); intersectionality is "not identity politics on steroids, it is a lens, a prism, for seeing the way in which various forms of inequality often operate together and exacerbate each other" (Kimberle Crenshaw in Steinmetz, 2020).
- **Academic productivity:** Academic or scholarly productivity[1] is the advance of science and knowledge as measured by the publication of scientific papers, presentations, and other modes of dissemination and measures of impact in the field (Way et al., 2019). While academic productivity typically centers on the publication of papers in high-status refereed journals, it may also include measurements of effective teaching and student learning (Altbach, 2015).

[1] In this report we use the terms "academic productivity" and "scholarly productivity" interchangeably, while also recognizing that there may be different interpretations of these terms by institutions and scholars.

- **Service:** Academic service consists of two categories: internal service is service to one's department, school, and/or university in activities related to faculty governance, recruitment, student admissions, and program development; external service is service to the profession and to local, state, national, or international communities (Guarino and Borden, 2017).
- **Work-life integration or "balance**": The integration of work and nonwork demands, the latter usually considered personal life, involves subjective assessments of "balance" and satisfaction in both work and nonwork roles (e.g., Greenhaus and Allen, 2011) and structural or organizational factors that affect this integration or balance, such as flexibility in work schedules and tenure assessments (e.g., Kosseck and Lambert, 2005; Moss, Salzman, and Tilly, 2005).

In this analysis, institution type refers to both Carnegie Classifications of institutions (e.g., doctoral universities, master's colleges and universities) and different categories of minority-serving institutions such as Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), or Tribal Colleges and Universities (TCUs).

In this analysis, intersectionality is operationalized by focusing on three aspects of scholars' identities (i.e., career status, race/ethnicity, and gender) and two aspects of instructional structures were examined (i.e., institution type, disciplinary affiliation). A focus on how these aspects of STEMM researchers' identities and institutional structures, which reside at a more macro level than many intersectionality studies, is due to the fact that in the literature most observations, datasets, and reporting are not fine-grained enough to focus on specific populations in specific contexts. A more thorough examination of the systemic inequalities that shape

opportunity for marginalized populations and subsequent implications for social justice activists, which is a core feature of intersectionality research (e.g., Harris and Patton, 2019) is beyond the purview of this chapter, and so a more delimited analysis of the ways that certain identities and institutional structures impact STEMM scholars lives during a global pandemic is provided here.

It is important, however, to consider the ways that these identities and structural forces intersect and interact in people lives, which is a core feature of intersectionality theory. This focus on the overlapping of identity and systemic forces is because narratives of discrimination and anti-racism too often depict identities as singular and mutually exclusive, such as a "woman biologist" or an "African American chemist" (see National Academies of Sciences, Engineering, and Medicine, 2020). Such an account may focus attention on how sexism impacts the career of a woman biologist, or how racism affects the African American biologist, both of which are important steps in recognizing that persons with these identities do have different experiences with tenure clocks and productivity than a white male scientist. However, such an approach overlooks the ways that an individual can occupy multiple, minoritized identities (e.g., a Black woman scientist), many of which are grounded in longstanding social and structural arrangements that privilege some groups over others, and that cumulatively impact and inhibit their opportunities and experiences (McGee et al., 2020).

Three primary topics related to the COVID-19 pandemic and its impact on the nature of STEMM academic work are reviewed here, with each analyzed using four "lenses" of intersectionality (see Table 1).

TABLE 1 Summary of Study Design

Topics in this Review	Intersectional Features
Impact of Pandemic on Academic Job Market	Researchers at Different Career Stages
Notions of Academic Productivity	Black, Indigenous, and People of Color
Institutional Responses to the Pandemic	Gender
	Discipline and Institution Type

Evidence of the impacts of the pandemic on some topics for particular groups (e.g., views of academic productivity for BIPOC scholars) were not yet available and thus are not included in this chapter. In other cases, however, considerable evidence exists on particular combinations of topics and intersectional features (e.g., academic productivity for women) and even for combinations of intersectional attributes (e.g., productivity for Black women). Thus, we consider evidence on the impacts of the pandemic on specific groups, and not on STEMM researchers more generally, which underscores the importance of an intersectional perspective. Ultimately, the impacts of the COVID-19 pandemic on the lives of STEMM academics cannot and should not be analyzed without first recognizing the pre-existing inequalities and racial, gender, and institutional dynamics that shape and constrain opportunity, productivity, and work-life balance.

REVIEW OF THE IMPACT OF THE PANDEMIC ON THE STEMM JOB MARKET

A brief overview of the impact of the COVID-19 pandemic on the academic STEMM job market provides an important context for considerations of the career trajectories of women and other minoritized populations. First, the impact of the pandemic on the overall labor market and the STEMM job market in particular is reviewed, followed by analyses of ways that these developments are disproportionately influencing the career prospects of researchers at different

career stages, of BIPOC scholars, women, BIPOC women, and finally of scholars in different types of postsecondary institutions.

The COVID-19 pandemic is truly a global event, expected to reach those in every corner of the globe, and disrupting business activity everywhere, even reaching those who are not integrated into the global commerce system. As the novel coronavirus spread from Wuhan, China, in early 2020 to Europe, North America, and the rest of the world, many governments responded by instituting stay-at-home orders, closing businesses and schools, and even closing national borders. Many businesses had to develop novel work strategies to address the financial burden impacting them (Willis Towers Watson Webcast, April 22, 2020), and in a survey conducted the week of March 23, 2020 among 812 North American companies, 42 percent of the companies already froze or reduced hiring, and 28 percent of the companies reported they would implement similar measures (Maurer, April 2, 2020). Many companies have also instituted furloughs, and these cost-cutting measures reached the academic sector: a PEW report (Rosewicz and Maciag, 2020) finds "82% of college and university presidents anticipated hiring freezes" and overall public education employment declined by over 8 percent, much higher than in most other industries.

The ultimate effects of the pandemic on the working population, in light of shutdowns and furloughs, can be seen as a "career shock," which is defined in vocational psychology as a "disruptive and extraordinary event" that occurs outside of an individual's control and "triggers a deliberate thought process concerning one's career" (Akkermans et al., 2020). Studies of the effect of recessions on labor markets finds a "scarring" effect on careers—with diminished

income and career advancement—even when delays in entering or losing employment is due to structural factors in the economy rather than individual factors.[2]

These career shocks or scarring have differential effects as a result of the interplay between individual (e.g., one's profession, education, or gender) and contextual (e.g., geographic location, local labor market conditions) factors. In labor markets, gender in particular plays a critical role in shaping how these disruptions impact a person's career trajectories, as historically, economic recessions in the United States have resulted in employment losses that were larger for men than women. Conversely, the COVID-19 pandemic recession has resulted in a significant reduction in women's employment and consequently, negative impacts on wages—which often leads to a loss of earnings that outlasts the recession itself (Alon et al., 2020). In the early part of 2020, the share of women who were working was the lowest since the mid-1980s, when labor force participation among women was much lower than the early 21st century (Kochhar, 2020). Overall, 4 times as many women as men left the labor force in September, 2020, and one in four women said it was due to lack of childcare (Kashen et al., 2020).

The disproportionate impact on women in the workforce is due to the combination of the types of jobs with high concentrations of women that were also hardest hit by the recession, and the lack of childcare also led to women leaving the labor force or reducing hours of childcare (Kashen et al., 2020). For example, the higher concentrations of women employed in low-wage jobs that require customer face-to-face interactions (e.g., hospitality, tourism, retail, restaurants) and thus were closed due to the pandemic, leading to the unemployment rate for women jumping

[2] Various studies find that graduating into a recession led to higher rates of unemployment and lower wages (e.g., Rothstein, 2019, found a higher unemployment of 2 percentage points; Oreopoulous et al., 2006, found a 10 percent wage gap compared to those not graduating during a recession, though the deficit faded over 8 years; others (e.g., Schwandet, 2019; Kondo, 2015; Daiji and Ayako, 2015; Kahn, 2010) found similar effects overall, and large income gaps, and employment in smaller firms and lower occupational attainment at higher rates for lower SES groups. Oreopolouos et al. (2006) found "a large degree of heterogeneity in the costs of recessions" (p. 34) and the "least advantaged, who suffer permanent earnings losses and are permanently down-ranked to lower wage firms" (p. 34).

by more than 12 percentage points between February and April of 2020 (Bateman and Ross, 2020; Mahajan et al., 2020). Additionally, industries such as retail, food service, and arts/entertainment tend to employ younger adults who are in entry level roles, working part time or seasonally, and people with lower levels of educational attainment, which is a combination of individual attributes that renders individual workers especially vulnerable to exogenous shocks such as the pandemic (Berube and Bateman, 2020).

Perhaps the most direct impact of the pandemic on the academic job market is the massive financial cuts that most colleges and universities are being forced to institute, given declines in revenue from tuition, campus housing, athletics, and other revenue sources (e.g., University of California at Berkeley, 2020; University of Minnesota at Rochester, 2020). With hiring freezes in place at many institutions, and even layoffs of tenured faculty and research staff, the job market in hiring education does not look promising, and is one of the critical issues negatively impacting STEMM researchers, especially early-career researchers. By the end of this summer, the Bureau of Labor Statistics reported the largest-ever decline in college and university employment: "At no point since the bureau began keeping industry tallies in the late 1950s have colleges and universities ever shed so many employees at such an incredible rate" (Bauman, 2020 — Chronicle of Higher Education, October 6, 2020; https://www-chronicle-com.proxy.libraries.rutgers.edu/article/how-the-pandemic-has-shrunk-higher-educations-work-force).

Impacts of the COVID-19 Pandemic on Prospects for Researchers at Different Career Stages

The impacts of the pandemic on STEMM academic researchers also appears to vary depending on individuals' career stage, with especially negative impacts on postdoctoral

researchers whose professional goals tend to focus on securing a full-time tenure-track faculty position. In a recent worldwide survey of 7,670 postdoc researchers in academia, which was translated into English, Mandarin Chinese, Spanish, French, and Portuguese, approximately 61 percent of the participants felt a negative impact by the COVID-19 pandemic. Twenty-five percent of the participants felt uncertainty regarding their future professional research careers (Woolston, 2020). One researcher in Brazil mentioned that some PhD-level researchers had resorted to selling food in the streets to sustain themselves and their family. Other postdoc researchers participating in this global survey expressed uncertainty about their visas expiring, thus inhibiting them from completing their research and publish their findings. Additionally, increased concerns about an inability to enter a country due to COVID-19 have been reported by postdoctoral fellows who were accepted to institutions in other countries. The three major concerns resulting from the COVID-19 pandemic detailed in this survey were (1) economic impact (40 percent), (2) increased competitiveness for funding (64 percent), and (3) scarcity of career opportunities (45 percent) (Woolston, 2020).

In some STEMM disciplines that require field research, the impact on early-career scholars may be particularly dire. In a letter in *Science*, Inouye et al. (2020) argue that the loss of data during entire field seasons can be catastrophic for long-term studies, resulting in lost data that may be crucial for a dissertation, postdoctoral project, or a scholar's early publications that can lead to academic jobs. The authors of this letter call on funding agencies to provide funding for salary, tuition, and fieldwork expenses for early-career researchers, which if targeted may have outsized (and positive) impacts on future generations of scientists (Inouye et al., 2020). Given that disruptions to a person in the early phases of their career can lead to their departing a profession and/or falling behind in terms of accomplishments and prospects for advancement,

these impacts to postdoctoral students and other early-career scientists should be a cause for concern among STEMM professionals, funding agencies and postsecondary institutions (Shaw and Chew, 2020).

Impacts of the COVID-19 Pandemic on Career Prospects of BIPOC Scholars

Before considering the impact of the COVID-19 pandemic on BIPOC scholars, it is important to first recognize the state of the STEMM workforce with respect to race, ethnicity, and diversity prior to the pandemic, in which there were pre-existing inequalities such that the pandemic did not impact a profession with equal representation across racial and ethnic groups. First, there are important racial differences in the composition of the STEMM workforce, with Blacks and Hispanics having the largest representation in healthcare fields, with approximately 37 percent of licensed practical and licensed vocational nurses being either Black or Hispanic. In addition, Blacks were underrepresented across all STEM fields but had the lowest percentage in life sciences (4 percent) and engineering (5 percent). Hispanics were also underrepresented with the lowest percentage in math (6 percent), while whites and Asians were overrepresented in STEM positions relative to their U.S. population, particularly in the workforce positions requiring higher levels of education. The vast majority of the Asian STEM workforce is foreign born (81 percent), and the majority of the Black STEM workforce is foreign born (22 percent) compared with the overall Black workforce in the United States (14 percent) (Funk and Parker, 2018).

Another notable point of variation in the STEMM workforce by race and ethnicity pertains to the number of doctoral degrees awarded in the United States. According to the National Science Foundation's Survey of Earned Doctorates, the number of Black or African Americans that obtained doctoral degrees in 2018 (n = 3052) was higher than that of only American Indians or Alaskan Natives (n = 115). Of those Blacks or African Americans obtaining

doctoral degrees, 80.5 percent were U.S. citizens (n = 2456) while 19.5 percent were not (n = 596). Yet a significant disparity was noted in the financial support received by Black scholars, which is a critical feature of a scholars' likelihood of success in higher education. Only 10.8 percent of U.S. citizen Blacks or African Americans (n = 265) were financially supported by teaching assistantships in obtaining doctoral degrees, while 28.3 percent of all non-U.S. Blacks or African Americans (n = 169) received teaching assistantships as financial support mechanisms in obtaining doctoral degrees. In 2018, 15 percent of U.S. citizen Blacks or African Americans (n = 368) were financially supported by research assistantships in obtaining doctoral degrees while 30.9 percent of all non-U.S. Blacks or African Americans (n = 184) were supported by research assistantships. Of all population groups receiving doctoral degrees in 2018, there was no population group (U.S. citizens or non-U.S. citizens) that received a smaller percentage of research assistantships than U.S. Blacks or African Americans. In fact, 41.2 percent of all U.S. citizen Blacks or African Americans (n = 1,012) who obtained doctoral degrees in 2018 were supported by their own resources (which may include student loans). This percentage of self-financing is higher than any other ethnic or racial group or any other citizenship group that obtained U.S. doctoral degrees in 2018.

In addition, the time to doctoral degree from receipt of the bachelor's degree is greatest in U.S. citizen Blacks or African Americans at 11.6 years and the time to receipt of doctoral degree from graduate school start is also longest in this population group at 9.7 years. The average age for the receipt of doctoral degree (median age = 36.0) U.S. citizen Blacks or African Americans is eclipsed by Native Americans or Alaskan Natives (median age = 36.3). U.S. citizens, on average (median age 31.8), are older at the age of receipt of a doctoral degree conferred from at U.S. institution compared with non-U.S. citizens who receive doctoral degrees from U.S.

institutions (median age 30.9). Consequently, these data indicate that for BIPOC scholars in the STEMM disciplines, the raw number of scholars in the academic pipeline, their level of financial support, and their time to degree was already in a disadvantaged position relative to white researchers.

Finally, disparities in pay should be acknowledged across different racial groups in STEMM occupations. Women working in STEM fields were paid less ($60,828) than men working in STEM ($84,000) on average. This 72 percent disparate gap in pay was partly reflective of the differing occupational subgroups of men and women. However, women working in STEMM fields tended to outpace the salaries of women working in non-STEM fields ($38,480). Black STEM workers received the lowest median average salary of STEM workers ($58,000) followed by Hispanics ($60,758) compared with white ($71,897) and Asian STEM ($90,000) workers. In STEM fields in the United States, Asian workers make 125 percent of the salaries of whites. Whereas in the U.S. non-STEM workforce Asians make 90 percent of the income of whites. Black STEM workers in the United States, who experience the greatest ethnic/racial pay disparity of STEM workers (81 percent) of whites, still have less disparate salaries than Black non-STEM workers in the United States (73 percent) (Funk and Parker, 2018).

While the specific impacts of the pandemic on BIPOC scholars have yet to be documented, early signs indicate that pre-existing inequalities are being exacerbated by negative impacts to scholars' financial situations and work-life balance. For instance, a survey of 3,345 academic institutions in Brazil found that students who identified as ethnic minorities were more likely than white students to experience "intense strain," and that only 47 percent of white or Black women with children compared to 77 percent white men without children had successfully submitted manuscripts during the pandemic (Woolston, 2020). Similarly, in an essay by a Black

woman hematologist (Carr, 2020), the author noted that persistent disparities in funding for Black scientists by NIH, low numbers of Black women in science, and institutional racism were pre-existing stressors that the COVID-19 pandemic and the civil unrest sparked by the killing of George Floyd only exacerbated. While Carr (2020) calls for institutional responses such as targeted recruitment and retention of Black women in STEMM fields, she emphasizes the importance of support systems for Black women researchers, who can recruit, support, and promote others in a field that presents many obstacles to their success.

Given that researchers have long documented the challenges that face women of color in the STEMM disciplines, these observations by Carr (2020) underscore the importance of addressing these longstanding inequalities. In fact, the ways that sexism and racism in the academy intersected in the lives of women of color was first documented in the influential 1976 report titled, *The Double Bind: The Price of Being a Minority Woman in Science* (Malcolm, Hall, and Brown, 1976). In this quintessentially intersectional analysis, the original study on the double bind and later works reinforced the importance of this perspective and the unfortunate fact that over 35 years later these challenges remained in the STEMM fields. In a special issue of *Harvard Educational Review*, Malcom and Malcom (2011) argue that the locus of bias had shifted from individuals to institutions, and Ong et al. (2011) similarly contend that institutions needed to more proactively support (and invest in) student-faculty mentoring relationships, access to professional development, and engagement in robust research opportunities for minority women. Given that the impacts of the COVID-19 pandemic are clearly disproportionately impacting women, as will be addressed in the next section, it is imperative that funding agencies, professional associations, and postsecondary institutions recognize that BIPOC women in the STEMM disciplines are at a particular (and historic) disadvantage.

Impacts of the COVID-19 Pandemic on Career Prospects of Women

As with BIPOC populations, women were already disproportionately represented in some fields of the STEMM academic workforce before the onset of the pandemic. Over the last few decades there has been an influx of women entering academic medicine, yet fewer advance in academic rank, which is similar to other areas of science, mathematics, and business (Chesler and Chesler, 2002; Nonemaker, 2000; Hewlett and Luce, 2005; Institute of Medicine, 2006; National Academies Press, 2020). In fact, research studies find only 1 percent of women are full professors among engineering faculty in the United States (Chesler and Chesler, 2002). The numbers are also grim for women in business, where only 6 percent are in high-ranking positions in Fortune 500 companies (Eagly and Carli, 2007). Furthermore, women faculty are generally paid less than their men colleagues and women of color typically spend more time mentoring students of color, yet often are not rewarded for it, since it's not part of the faculty-reward structure (Pettit, 2020).

The field of engineering demonstrates the greatest sex disparity at the doctoral level in the United States with 75.9 percent of all doctoral degree recipients being men, followed by mathematics and computer science with 75.4 percent of all doctoral degree recipients being men. Despite the low percentage of women obtaining engineering doctoral degrees in the United States, there has a continuous steady increase in the number of women obtaining doctoral degrees in engineering (from 6.8 percent in 1988 to 24.1 percent in 2018). The smallest percentage of gender disparity in the field of mathematics and computer science at the doctoral degree level in the United States was seen in 2008 when 26.1 percent of all mathematics and computer science doctoral degree recipients were women. A decline was seen in 2013, when the number of women obtaining mathematics and computer science degrees at the doctoral level

reverted back to 2003 levels at 23.1 percent. However, the number of women obtaining mathematics and computer science doctoral degrees in the United States also continues to increase (from 14 percent in 1988 to 24.4 percent in 2018). There are also notable gender differences in certain STEMM occupations. For instance, in medicine and healthcare, women accounted for the majority of healthcare practitioners and technicians, but were underrepresented in engineering and computer jobs. Women accounted for the majority of nurses (89 percent) and dental hygienists (95 percent) (Cimpian, 2020).

Yet there have also been important advances made by women in STEMM occupations. Prior to the pandemic, the number of women receiving doctoral degrees in select STEM fields (life sciences) and other fields (education, psychology) had steadily increased from 1988 to 2018. Between 2003 and 2008, there was a shift in the number of doctoral degrees conferred in the life sciences from mostly men (men receiving 51.7 percent of all life sciences doctoral degrees in 2003) to mostly women (women receiving 52.9 percent of all life sciences doctoral degrees in 2008). This shift has been on a study climb since 1988, with women obtaining 55.7 percent of all life sciences doctoral degrees. In fact, in 2018, women accounted for 50 percent of all U.S. workers in STEMM occupations (Pew Research Center Analysis, 2018). This was considered a significant workforce gain and economic indicator of the impact of STEMM careers for women.

Although women have made significant gains in the life sciences and medicine in terms of initial entry and numerical representation at the junior ranks (e.g., see Collwell's [2020] account of her pioneering career beginning in science labs to becoming director of NSF), the longstanding career challenges and barriers to advancement and equity have been slow to change. In other fields such as engineering, computer science, and the physical sciences, there is much less progress and

continued underrepresentation of women in these disciplines (Beede et al., 2011). There persists gender bias in peer review, hiring, and promotions, and stereotypes that men are smarter and more interested than women in STEMM careers (Ertl et al., 2017), despite evidence that, for example in mathematics, women perform as well men and pursue the field as undergraduates in equal numbers as men (Douglas and Salzman, 2019; Weinberger, 2005)

These problems are now being compounded by the pandemic, which is likely going to disproportionately impact the careers of women across academia but particularly in the STEMM fields (Hansen, 2020). The stay-at-home orders issued by national and state governments in the early part of the COVID-19 pandemic led to many schools and childcare facilities to close, forcing many parents to work from home while also caring for dependent children. Given that even before the pandemic, far more women in STEMM fields left their professions (43 percent) compared to men (23 percent) after having their first child (Cech and Blair-Loy, 2019), and that women generally shoulder more childcare and household responsibilities than men (Jolly et al., 2014), it is not surprising that many scholars are calling on postsecondary institutions to provide childcare supports, increase funding opportunities, and to carefully manage tenure and promotion criteria (e.g., prioritize women-authored papers, monitor teaching and service responsibilities) (Cardel et al., 2020). The specific ways that the pandemic is impacting academic productivity for women, and subsequent institutional responses, will be addressed later in this chapter, but it is important to note that while definitive data on the impacts of the pandemic on the long-term career prospects of women in STEMM are not yet available, we can observe the ways in which disruption to society and academia caused by the pandemic will exacerbate pre-existing inequalities regarding domestic and childcare responsibilities, with direct implications for career outcomes of women in STEMM fields.

Impacts of the COVID-19 Pandemic on Career Prospects for Scholars at Different Types of Institutions

A considerable body of empirical evidence exists demonstrating that resources, including federal research grants, are disproportionately allocated to high-prestige research universities, which leads to a national landscape that some call, "Unequal Higher Education" (Taylor and Cantwell, 2018, 2019). In fact, approximately 50 percent of all STEMM research funding goes to about 100 doctoral-granting institutions, leaving the other 3,900 institutions in the United States—which include community colleges, regional comprehensive universities, and minority-serving institutions—competing with one another for the remaining funds. Furthermore, researchers have documented considerable disparities in state and federal funding for HBCUs, with many state governments prioritizing Predominantly White Institutions (PWIs) (Boland and Gasman, 2014; Minor, 2008), leading minority-serving institutions operating with less institutional support for STEMM research activities.

Consequently, the impact of the COVID-19 pandemic on individual STEMM scholars depends not only on their race, gender, or disciplinary affiliation, but also the type of postsecondary institution where they work. As an engineering scholar at Florida International University said, "Even before the pandemic HBCUs faced unique challenges, most of them a direct result of extensive and varying levels of inequity compared to PWIs" (Hernandez-Alende, 2020).

Although PWIs have increased opportunities for underrepresented minorities in STEMM fields, HBCUs continue to train substantially higher numbers of STEMM majors. As Weinberger's research shows, HBCUs were the institutions primarily responsible for expanding opportunities in engineering and computer science for Black students and largely responsible for

addressing the racial gap in these fields through their early and sustained expansion of engineering and computer science programs (the gap is still quite large, but she finds the HBCUs increase in the number of Black graduates during the expansion of these fields beginning in the 1970s kept the gap from growing). In fact, the early introduction of computer science courses at HBCU campuses was so successful that Black college graduates became more likely than the U.S. average to hold a computer science degree (Weinberger, 2018, 88).

As funding agencies, policymakers, and institutional leaders consider how to allocate scarce resources in the postpandemic world, it will be critical for them to recognize that because minority-serving institutions have, and continue, to train substantially higher numbers of STEMM majors than PWIs, institutions such as the HBCUs are uniquely qualified to address increased inequities in STEMM that are resulting from the pandemic.

IMPACT OF INSTITUTION TYPES ON THE PRODUCTIVITY OF WOMEN DURING COVID-19

As demonstrated in the publication by Squazzoni et al. (2020), the number of manuscripts submitted and reviewed during COVID-19 were significantly higher for men rather than for women. The pandemic provided additional time for men to submit publications, whereas for women a significantly negative effect was seen in publication rates by women in academic STEMM in all fields, except the life sciences. An increase in negative production was noted by seniority, with a decrease in journal submissions by tenured and tenure-track faculty which is compared with doctoral students and those without doctoral degrees.

Prior to the pandemic, HBCUs were known for having faculty who are committed to service as much as to research (U.S. Dept. of Ed., 1991). Traditionally, the faculties at many

HBCUs place as much or more emphasis on teaching and student service-oriented activities as on research. Minority faculty of color at primarily white institutions (PWIs) are told to stay away from service (Matthew, 2016). While faculty at HBCUs are told to embrace service as a part of the institutional culture (U.S. Dept. of Ed., 1991). Nonetheless, BIPOC faculty at PWIs do continue to perform "invisible work" such as mentoring students and serving on committees (Johnson, 2020).

Much of this mentorship and service is to underrepresented STEM students. Dr. Laura Kiessling described this as a "catch-22." If you join in "you're penalized," if you don't join in "you're penalized." Yet even with the messaging that many HBCUs provide for the need for service to the student population, this service is not regarded or rewarded in the same way as research productivity (e.g., generation of scientific papers, peer-reviewed publications, and grants funded) (Wang, 2019). Although there has been debate and unwritten rule that careful measurements of effective teaching and student learning (Altbach, 2015) should be included in productivity, teaching and service typically are not, regardless of institution type. For example, a rural HBCU has a different focus on productivity than a primarily white research institution in an urban area does, and yet, the definition in the literature remains the same. Our research has identified this fact (Figure 1; Figure 2). Among full-time faculty, women are concentrated in non-tenure-track positions. Further, faculty of underrepresented minority (URM) populations (non-white and non-Asian) make up 12.9 percent of all full-time faculty positions in higher education, although URMs make up 32.6 percent of the U.S. population.

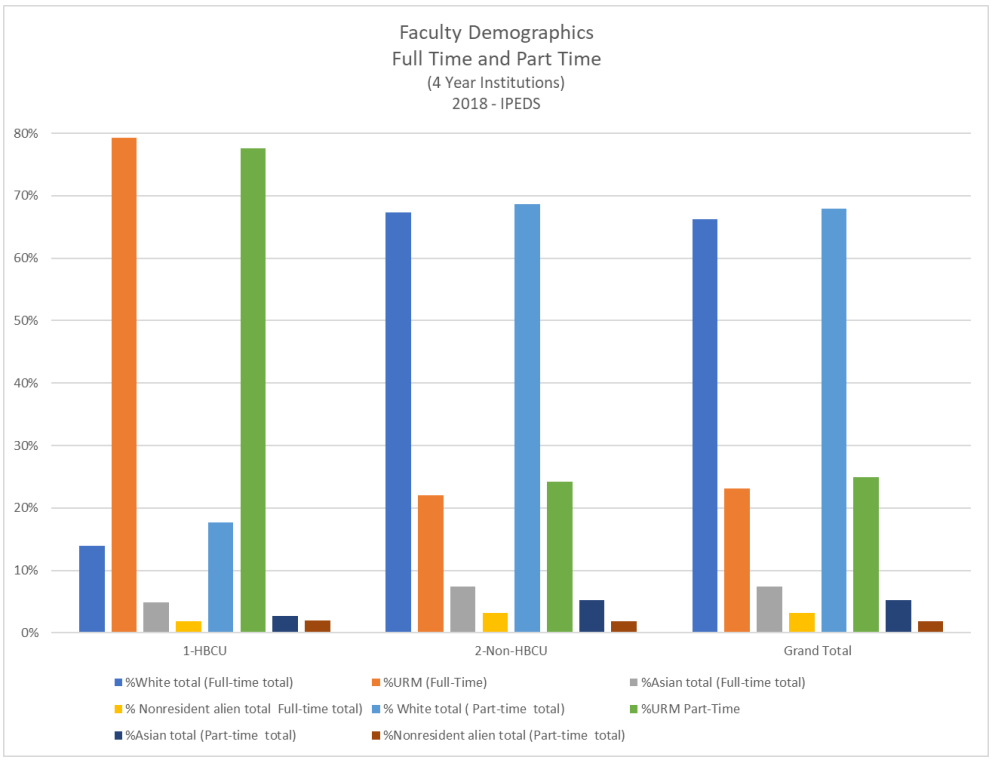

FIGURE 1

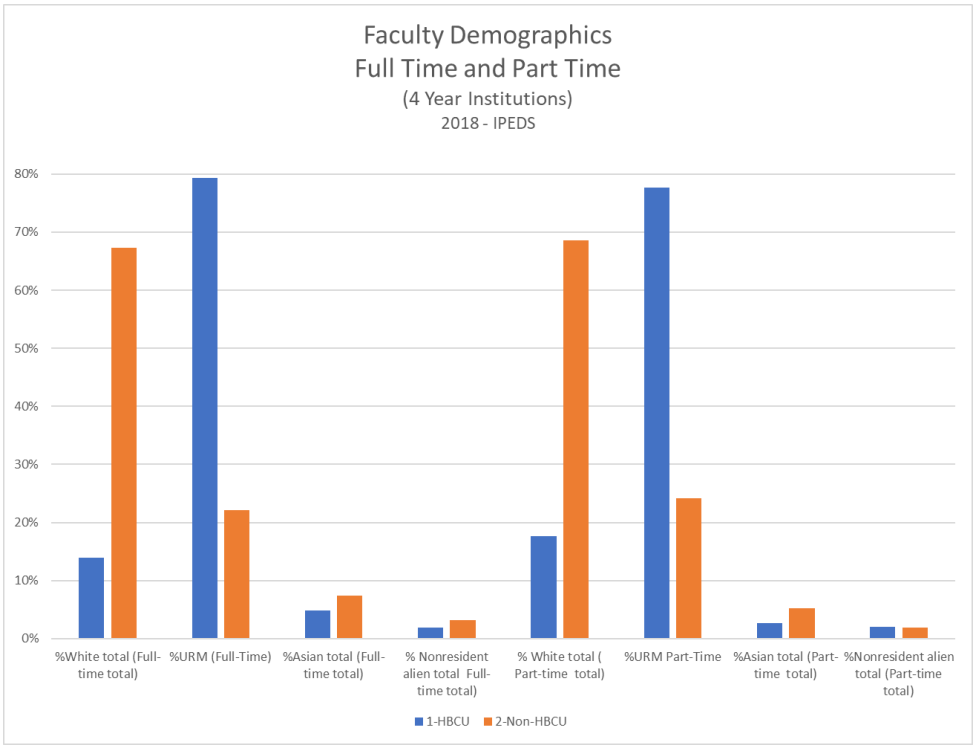

FIGURE 2

Impact of Institution Type on the Productivity of Black Women During COVID-19

According to IPEDS data from 2018–2019, the representation of women at the ranks of faculty decreases by progression in Carnegie institution type. Women represent 54.7 percent of faculty at non-profit, associate's degree-granting postsecondary institutions, 47 percent of faculty at bachelor's degree-granting institutions, 49.8 percent of faculty at master's degree-granting institutions, and 42.3 percent of faculty at doctoral degree-granting institutions (AAUP, 2020; (Salzman, 2020). In 2015, 96 percent of the nation's tenured Black college faculty were employed HBCUs (*Washington Post*, 2015). Similar to what was seen in 2015 following the protests over racial tensions at the University of Missouri campus, many universities and organizations are hiring more vice presidents for diversity and convening more diversity committees following the 2020 Black Lives Matter movement that spurred at an international level during the COVID-19 pandemic. However, similar to what was stated by researchers and authors in response to the 2015 protests, based on similar faculty numbers from 2015–2019 as included in the IPEDS database, we agree that "the best plan for increasing the number of black faculty is not convening a new diversity committee or appointing another vice president for diversity, it's hiring more black presidents, deans and department chairs at TWIs" (i.e., PWIs) (*Washington Post*, 2020; IPEDS, 2020).

As of 2019, the vast majority of tenured Black women faculty were employed at HBCUs. While the number of undergraduates overall declined sharply only for Black undergraduates and men undergraduates during the pandemic summer of 2020 compared with last summer (2019), the number of Black undergraduates enrolled at HBCUs during the pandemic summer of 2020 increased (Fain, 2020; NSC, 2020). Additionally, while the number of undergraduates overall declined for fall 2020 versus fall 2019, the number of undergraduates enrolled at HBCUs

nationwide showed an increase in fall 2020 enrollment versus fall 2019. The increase in the number of students attending HBCUs, during worldwide pandemic has also increased the number of students seeking faculty assistance both personally and academically at this time. This is particularly true at public HBCUs in the south (also where many public HBCUs are located) as many of these institutions, along with their state university systems, were required to resume in-person learning for the fall 2020 semester (Valbrun, 2020). The impact on the institutional faculty and staff with the increase in student enrollment during the pandemic also increased the number of students seeking out faculty assistance both personally and academically. As a result of the large number of Black women faculty located at HBCUs, it is difficult to tease out the data regarding the impact of institution type on Black women faculty during the pandemic.

REVIEW OF THE IMPACT OF THE PANDEMIC ON NOTIONS OF ACADEMIC PRODUCTIVITY

An important, if less visible and longer-term impact of the pandemic is on academic productivity, which, in turn, will influence the career trajectories of STEMM researchers. While many equate the notion of academic productivity with research-related metrics that are highly valued in research universities, such as publications in prestigious peer-reviewed journals, competitive research grants, and research-related awards, academic productivity is much broader and varied by institutions. The topic of productivity in higher education is debated and rather contentious.

The debates around academic productivity tend to center on three issues. The first is the critique that research-focused metrics overlook the importance of the other two facets of most institutions' tenure and promotion policies—that of teaching and service (Altbach, 2015). The

second is that conventional measures of productivity (and thus the language of production), which often focus on the ratio of worker hours to production units, are inappropriate for the nature of academic work, which includes activities such as student mentoring and course preparation that may not appear in quantifiable measures (Reagan, 1986), as well as the measures themselves not necessarily reflecting the value or importance of research and academic work (although the estimates vary by discipline and measure, and are often disputed, overall findings typically show more than half of publications in scientific journals are not cited and citation rates appear to be declining (Bauerlein et al., 2010) . The third is well-established disparities in academic publishing by gender (e.g., Raj et al., 2017) and race (e.g., Mendoza-Denton et al., 2017), as well as gender biases in citations, which raises questions about the disparate effects of using these measures for making decisions about promotion and retention.

The pandemic is thus exacerbating the gender differentials in academic productivity and the effect on career progression. In the remainder of this section, we review some of the emerging literature on this point, which largely centers on the ways that gender is negatively impacting STEMM scholars' publishing during the COVID-19 pandemic.

Impacts of the COVID-19 Pandemic on Productivity of Women

The widespread lock-down measures and school closures imposed by federal and state governments in response to the COVID-19 pandemic has disproportionately penalized women academics, who are more likely to be responsible for childcare at home, adding further challenges to overcoming inequalities in the academic workplace. Studies on domestic labor have long documented that women perform more childcare and housekeeping responsibilities than men, even in dual-academic households (e.g., Bianchi et al., 2012), and this dynamic

continues in 2020 with women academics bearing the brunt of domestic work and childcare (Oleschuk, 2020).

This added burden may be reflected in early studies on academic publishing finding women's share of first and overall authorship in COVID-19–related papers has decreased by 23 percent and 16 percent, respectively (Andersen et al., 2020). Moreover, papers on COVID-19 published in the prestigious medical journal *The Lancet* had low female authorship and were also affiliated mostly with institutions in high-income countries (Gabster et al., 2020). Krukowski et al. (2020) found "significant disparities were observed in academic productivity by gender and child age during the pandemic," with women reporting "a significant decrease in first and coauthor's article submissions, whereas no significant differences in productivity were reported by men."

The negative impacts of the pandemic on the productivity of women in STEMM fields is being discussed in a number of articles on the topic, along with recommendations for the ways institutions can address these growing inequalities (e.g., Cui et al., 2020; Guatimosim, 2020; Kibbe, 2020; Malisch et al., 2020; Oleschuk, 2020). In a paper that went viral due in part to its accessibility but also its resonance with the experience of many women in STEMM fields, Kreeger and colleagues (2020) offered "ten simple rules for women principal investigators during a pandemic," in response to the fact that the pandemic was negatively impacting women PIs, who tend to carry higher teaching and service loads than men (e.g., Guarino and Borden, 2017). These rules include a suggestion to find peer groups of women to provide support, saying no to nonessential responsibilities, dropping certain projects and tasks, and pushing back on demands to be more productive (Kreeger et al., 2020).

Of particular concern is the impacts of the pandemic on the careers and professional advancement of women in academic medicine, who have been forced to address a highly stressful (and potentially dangerous) workplace on top of added responsibilities at home (Madsen et al., 2020). In addition, pre-existing inequalities in the medical workforce, where women are more likely to have teaching-related roles instead of funded research positions, which translates into higher clinical workloads than many men in the field, should also be recognized as a key aspect leading to the differential impacts of the pandemic on women in academic medicine.

Impacts of the COVID-19 Pandemic on the Productivity of Scholars at Different Institution Types

While our review did not reveal any studies or reports addressing differences in the academic productivity of STEMM researchers at different institutions (e.g., PWIs, HBCUs, community colleges; large research universities and small liberal arts colleges), it is important to recognize the aforementioned differences in funding and research support systems provided to scientists in different types of colleges or universities. Consequently, it can be hypothesized that a STEMM researcher at an HBCU, where scholars typically receive less research funding and have higher teaching loads than at PWI research universities, may have fewer opportunities to publish in the midst of a crisis like the pandemic. However, future research will be required to isolate the impacts of institutional affiliation on academic productivity during the pandemic, if such differences do exist.

Impacts of the COVID-19 Pandemic on Institutional Responses to Academic Productivity

The responses of postsecondary institutions to the pandemic is uncharted territory. The Great Recession of 2008 posed financial challenges directly (e.g., to their investment portfolios)

and indirectly (reduced state revenues led to declines in some public institutions); there was also an increase in graduate enrollments in particular, which increased revenue. The devastation of Hurricane Katrina fundamentally altered the structure and mission of some the region's colleges: some departments were eliminated, tenured faculty were dismissed, and college programs were restructured, along with the dispersion of students to other colleges, but overall the "rebuilding" the education system was often applauded in popular accounts of the post-Katrina region. Less often noted was the unevenness of the recovery with fewer resources and the much slower recovery in institutions serving minority students, such as Southern University at New Orleans, and other HBCUs that waited years before receiving funds to rebuild and experienced greater losses of students and capacity to support faculty (Mangan, 2015).

In reviewing recommendations for institutional responses to the COVID challenges, it is important to consider not just the differential impacts on women and BIPOC groups, but also in the capacity of different institutions to respond and support women and minority groups (either within their institutions or for the institution overall), as seen in the aftermath of Katrina.

EXTENSIONS: WITH AND WITHOUT FUNDING

In 2020, several types of institutional responses have been observed, which tend to focus on providing faculty and other researchers with extensions (generally for funding) and alterations to tenure and promotion policies. In addition to college and university changes in policies, many funders are allowing extensions on projects and other adjustments as necessary. If PIs are unable to complete their research within the original timeframe, funders are being more flexible allowing (1) a no-cost extension, (2) revisions to the original budget, or (3) costed (supplemental) extensions if offered by the funder (University College London, September 2,

2020; National Institute of Health Research, March 16, 2020). The National Institute of Health Research is allowing clinicians to extend their research work if they postponed a career development award to aid frontline workers. In addition, funding will not be withdrawn by a delay in starting research (National Institute of Health Research, September 2, 2020). The Alzheimer's Association, the world's largest non-profit funder of dementia research, recently submitted guidelines for the Alzheimer's Association Rapid Program in Dementia (RAPID). This program aims to provide additional resources for gaps in resources and knowledge to early career awardees who currently have an Alzheimer's award but their research has been impacted by COVID-19. Awardees can request up to $50,000 for up to 1 year (Chavez, 2020). The National Science Foundation is providing the Rapid Response Research (RAPID) to researchers conducting nonmedical and nonclinical research to better understand the spread of COVID-19. Proposal budgets can be up to $200,000 for up to 1 year (National Science Foundation, 2020). Other funders offer similar programs which can be found on their respective websites.

Although many, if not most, funders have modified their policies to allow greater flexibility to researchers, lab closures and other delays will extend the time of the research projects and thus findings and publications, which may affect academic productivity. Moreover, even though funder policies allow for flexibility in project extensions, there is often no additional funding to support for staff and graduate students over the longer project period.

PROMOTIONS AND TENURE POLICIES AND DECISIONS

The wide range of direct and indirect effects of COVID-19 on academic productivity and careers is being considered by some institutions. For example, extension of the tenure clock is being implemented by a wide range of colleges and universities, such as Stanford University of

Texas, and University of Washington's 1-year extension to tenure-track faculty. However, according to Dr. Guarino at the University of California at Riverside, extending the tenure clock tends to put off financial incentives and career advancement and freedom (Pettit, 2020); thus extensions during this pandemic may be important for some faculty members, yet they can also be unhelpful for career trajectories. One argument during COVID-19 is to not penalize junior faculty for not publishing their research but to impartially evaluate them for unpublished research while they engage in other avenues of expertise (Connolly, 2020). Additionally, external reviewers must be mindful of incongruent effects among certain ethnic groups. For example, Dr. Gonzales at the University of Arizona reported Blacks and Native Americans have higher death rates due to COVID-19, and Asian American faculty are experiencing new forms of racism (Pettit, 2020).

It is important to note that the 1-year extensions and grant extension flexibility are helpful, but overall, the differential impacts on women may not be sufficient to address the added burdens of childcare and home responsibilities that affect work-life integration. Also to consider are the direct disparate impacts of COVID on BIPOC groups, such as higher infection rates and severity, and the indirect impact of added stressors may have differential effects in the resources for recovery.

CONCLUSION

The impact of COVID-19 on academic productivity and career trajectories cannot be adequately evaluated without acknowledging the intersecting identities and structural forces impacting different groups of STEMM researchers. The issues outlined in this report—how the COVID-19 pandemic has impacted the academic STEMM job market, institutional responses,

and notions of academic productivity lays out in different ways depending on the unique circumstances of individual institutions, regional and local labor markets, and individual STEMM researchers and faculty members. This is not solely an argument that "context matters" in dictating how national phenomena unfold in local settings, but is also a recognition that the individual lives of STEMM scholars and how they see themselves and their opportunities, are deeply embedded in and shaped by these overlapping spheres of influence.

While considerable debate exists in the social sciences about theoretical nuances and methodological implications of intersectionality theory, at the very least it is a useful heuristic or framework with which to try to understand how the various and overlapping forces of discrimination may impact an individual (Harris and Patton, 2019). Such a perspective is especially relevant in 2020, when the COVID-19 pandemic illuminated discrepancies in how working women were impacted by both increased childcare demands brought on by the massive shift to online schooling and workplace stressors that impacted the mental health and well-being of many working adults. Specifically, women, women of color, and other minoritized individuals were impacted by the deteriorating STEMM job market, institutional responses, and ideas of academic productivity during COVID-19. In response to the varied (and mostly negative) impacts of the pandemic on the lives and careers of STEMM scholars, we conclude this chapter with a brief summary of recommendations on how the higher education sector can best serve and support minoritized populations of STEMM researchers.

- Include primary caregivers in institutional decisions on how to address disparities brought on by the COVID-19 pandemic (Madsen et al., 2020).

- Provide additional supports to women through access to safe childcare (Gabster et al., 2020), create support groups for professional women, create solutions for emergency leave and workload reductions, and cancel all nonessential service (Kreeger et al., 2020).
- Provide extensions for funding and tenure clocks, while being mindful that these policies may not completely address underlying causes of decreased productivity (Kibbe, 2020).
- Journal editors should solicit articles from women scientists, and prioritize reviewing their submissions in a timely manner.
- Actively recruit and attempt to retain BIPOC women in STEMM, with close attention to ensuring that workplace climates are free of racist and discriminatory behaviors and that scholars have support networks in place (Carr, 2020).

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