Understanding the Experiences of Black Women in STEM: A Framework for Interruption (Research)

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Understanding the Experiences of Black Women in STEM: A Framework for Interruption

Abstract

Enhanced participation of Black women in science, technology engineering, and mathematics (STEM) is of ethical imperative, and empowering individuals who would otherwise not be able to fully engage in STEM increases our national potential to advance science and solve real-world problems. In this paper, we share a conceptual framework that seeks to define the "interruptions" experienced by Black women in STEM as they navigate undergraduate STEM programs. Our framework, grounded in Black feminist epistemologies, is informed by two years of data collected from surveys, interviews, focus groups, reflective journals, and audio diaries of forty Black women undergraduates at three institutions of higher education. This framework illuminates the relationship between societal power structures, Black women's STEM self-concept, and selected coping strategies. Although the framework was originally designed to understand how interruption impacts Black women in STEM, we believe it can be applied in other contexts and has the potential to serve as a guide in answering questions of persistence and retention.

Introduction

Imagine waking up in a body that is racially different from your own. That is what happens to Ruby Baptiste in HBO's *Lovecraft Country*, Season 1, Episode 5, Strange Cases. The HBO series *Lovecraft Country* is an adaptation of the 2016 dark fantasy black horror novel by Matt Ruff and explores the connection between the horror fiction of H.P. Lovecraft and racism in the United States during the Jim Crow era. In this episode, Ruby Baptiste, a Black woman, undergoes a physical metamorphosis after taking a potion from her White, male, intimate partner, William. At first, she is startled by her new appearance. She tells William, "It scared the shit out of me to wake up as white," but given the opportunity from William (with a stack of money and the potion) to "do as you please, go as you please in whatever skin you like," Ruby takes another dose of the potion and re-enters society as a white woman the following day. As Ruby is afforded pleasantries, access, and free ice cream throughout the day, Ntozake Shange's *For Colored Girls Only* plays in the background of her journey. She is able to sit in the park, read the newspaper, live life the way she wants, and simply take in the beauty of the day [1].

That evening, while drying Ruby off after her bath, William notices the empty potion jar and realizes she hasn't taken the money he left for her. Curious, he asks why she didn't use the money. Ruby looks at him and replies, "I didn't have to. I enjoyed my entire day using the only currency I needed ...whiteness" [1]. Her next statement to William sums up her experience of being a White woman in contrast with her life as a Black woman:

> "I don't know what's more difficult: being colored or being a woman. Most days, I'm happy to be both, but the world keeps interrupting, and I am sick of being interrupted" [1].

Ruby's statement, an homage to a quote from Roxane Gay's book, Bad Feminist [2], resonated deeply with us. We felt the origins of her exhaustion because, as Black women, it was the same

as our own. We were amazed that she was able to capture all that generational trauma and subjugation in one word: interruption. We reflected on interruptions in our lives as Black women and kept returning to our experiences in STEM. So finally, we asked ourselves the question: **What *actually* constitutes an interruption in STEM?** Although our individual journeys differed across our STEM disciplines, we all faced common challenges, or what Patricia Hill Collins calls a "Black women's standpoint" of systemic racism, gender bias, stereotype threat, and a variety of other forms of marginalization while pursuing our STEM degrees and attempting to find success in STEM fields [3].

As Black women, we navigate a world where the stereotypes assigned to us place us in positions of subservience to others, thus rationalizing our continued oppression [4], [5]. Black women are often placed in a "double bind", asked to prioritize race or gender in social justice causes [6]. In 1973, this double bind, along with continued disregard for the concerns and needs of Black women within the mainstream feminist and Black civil rights movements, led to the creation of the National Black Feminist Organization and paved the way for what we now know as Black feminist epistemologies [4], [7], [8]. These epistemologies seek to provide a theoretical viewpoint that "affirms, rearticulates, and provides a vehicle for expressing in public a consciousness that quite often already exists. More importantly, this rearticulated consciousness aims to empower African American women and stimulate resistance" [4, p. 32].

By documenting the experiences of undergraduate Black women in STEM as they progress through college, using a research design grounded in Black feminist epistemologies, we present a conceptual framework for interruption that investigates the relationship between societal power and Black women's experiences in undergraduate STEM programs.

Previous Explanations of Low Participation of Black Women in STEM

Many studies have been conducted seeking to better understand the experiences of undergraduate Black women in STEM and develop solutions to increase recruitment and retention [9], [10]. These studies can be broadly grouped into individual- and system-level solutions.

Studies that offer individual-level solutions often suggest behavioral interventions to increase persistence [11], [12]. Whether through assisting Black women in developing community (mentoring, cohorts, summer programs) or strengthening perceived academic deficiencies (tutoring, remediation courses, etc.), these solutions may improve the short-term experiences of some Black women [13], [14], [15]. However, when solutions seek to change individuals while ignoring systemic barriers, it leads to outcomes that are at best temporary, and at worst detrimental to long-term success.

Many of these individual-level solutions are responding to the pervasive metaphor of the "leaky STEM pipeline" that many Black women "fall through" at different points in their STEM journeys. Unfortunately, as Collins and Bilge point out, this metaphor, and the corresponding intervention programs developed using the metaphor, do not effectively call attention to and interrogate the systemic and structural barriers of United States society that are purposely

designed to block the path of Black women:

> The language of pipelines, with its related metaphors of leaky places from which talent leaks out, has increasingly replaced structural analyses with their language of barriers to achievement. The problem is represented as cracks in an otherwise sound pipeline in places that allow girls of color seemingly to leak out. In contrast, the structural barriers metaphor pays far more attention to the organization of formal education itself, suggesting that inadequate funding creates the barriers that block the achievement of women and girls of color [16, p. 205].

Research seeking to determine system-level solutions illuminates how structures impact individual experiences. Instead of trying to change the individual, solutions are centered on shifting systems by examining institutional culture, highlighting root causes of historical inequities, and dismantling barriers to entry [17], [18]. These studies are often grounded in intersectionality, which posits that the experiences of Black women can only be understood by carefully considering unique experiences for those living at the intersection of multiple identities, such as race and gender. [16], [19]. [20]. In addition, intersectionality asks researchers to not solely focus on the ways individuals adapt in the face of oppression, but also better understand the systems and structures that lead to that oppression [16], [20].

Within undergraduate education, much of the historic work on campus climate, STEM Culture, and STEM persistence has been examined through the lens of "fixing" marginalized students by providing additional resources to "remediate and assimilate" into the traditional white space [21], [22], [23], [24], [25]. Few studies investigate the relationship between these systems-level experiences (institutional, campus, and department) and the persistence of undergraduate Black women in STEM. Our model combines these two ideas by acknowledging the need for individual-level and system-level solutions. Our interruption framework also takes into account how these interruptions trigger a dynamic cycle of STEM self-concept, stress, and coping.

The term interruption is commonly used to characterize a verbal disruption of speech, but we utilize a broader definition: "something that causes a stoppage or break in the continuity of something" [26, Definition 2]. Although interruptions are daily occurrences in the lives of all people, we posit that health, income, and educational disparities for Black women point to Black women being interrupted more frequently than others [27], [28], [29]. Thus, it stands to reason that in STEM education Black women also face more interruptions due to the white supremacist structures and ideologies inherent in STEM culture [30]; over time, ongoing interruptions can result in an inability to persist, thus contributing to the low retention of Black women in STEM [31], [32].

Development and Validation of Framework

The framework presented here is the result of two years of data collected from undergraduate, Black women in STEM, as well as an iterative process that challenged the project team to make connections between the documented experiences of our participants with larger concepts of power. Grounded in Black feminist epistemologies, the site, higher education, and the subject, STEM education, are representative of the broader experiences of Black women who seek to enter and be included in traditionally white spaces.

The three partner institutions selected as research sites represent a cross-section of populations, locales, and institutional histories and cultures, including two historically black colleges and universities (HBCUs), one rural university, one women's college, and one predominantly white institution (PWI). Participant recruitment began in October 2022, and in an effort to include a diverse group of first-year, undergraduate, Black women, applications included questions about family financial and educational background, hometown, perceived high school academic preparation, and long-term career goals. All applications were thoroughly reviewed and discussed by the entire research team before the final forty (40) participants were selected.

The data collected (reflective journals, surveys, interviews, focus groups, and audio diaries) to uncover the experiences of interruption by Black women in STEM are consistent with Black feminist epistemologies. Reflective journaling is considered a culturally relevant way to collect data and is highly utilized in Black Feminist womanist research [33]. Open-ended surveys, interviews and focus groups, when analyzed using an intersectional lens, provide an explanation for an experience of inequality, and audio diaries are widely used to illustrate the complexities of individual and collective identities and social dynamics through real-time reflection [34], [35].

During the fall 2023 focus groups, participants were presented with a first glimpse of the emerging themes and constructs for interruption. Participants were asked for feedback as well as any other themes/constructs that might not have been captured. Additionally, participants were asked to give specific examples of said themes/constructs to assist the research team in better understanding how they manifest daily.

Based on feedback received during this focus group, as well as one and one-half (1½) years of participant data, the first iteration of our framework for interruption was developed by the project leadership team in December 2023. This framework was then presented to the entire project team and refined through multiple facilitated discussions. To continue validating the framework, we sought feedback from individuals outside of the project team. The framework was presented at the 2024 National Conference on Race and Ethnicity (NCORE), as well as to the project's advisory board in August 2024, and revised accordingly based on feedback received. In keeping with the Black feminist epistemologies, the revised framework, as shown in this paper, was presented to project participants during the fall 2024 focus groups.

We acknowledge that this, most likely, is not the final form this conceptual framework will take. We plan to continue to validate its usefulness and accuracy based on application to current and future participant data, feedback from our participants, and expert focus groups.

A Framework for Interruption

Black feminist epistemologies, including intersectionality, highlight that the matrix of domination (figure 1) constructs and reinforces social inequalities, and hierarchical position, based on race, gender, and other identities, and influences the ways individuals and groups experience these inequalities [3], [16], [36]. According to our framework for interruption, these

intersecting domains of power impose themselves on Black women in unique ways, causing ongoing interruptions, and impacting intent to persist.

To understand our framework, one must first understand how the matrix of domination uniquely impacts undergraduate Black women in STEM.

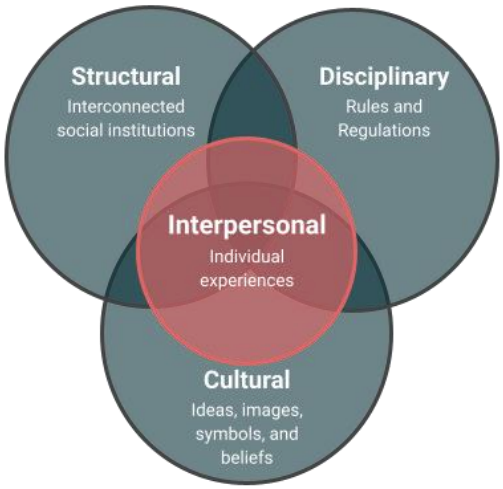

Figure 1. Matrix of Domination [16]

The site of our project, institutions of higher education (IHEs), use exclusionary admissions policies, astronomical tuition costs, and cultures rooted in white supremacist ideologies to maintain the current social conditions, including the subjugation of Black women [30], [37], [38], [39]. This places IHEs, like other social institutions, as agents of the structural domain of power. Most jobs, and especially those in STEM, require postsecondary education. This gives IHEs a high level of power as gatekeepers to long-term financial and social well-being [40], [41]. However, even though Black women represent approximately 7% of the population, only 4.8% of 2020 bachelor's degrees in STEM were awarded to Black women [42], [43]. When individuals are unable to successfully navigate racist and sexist experiences within IHEs and choose to leave STEM, the entire system of social inequality, from health care to housing to generational wealth, is maintained.

For those Black women who do continue to pursue degrees in STEM, constant adaptation to changing rules is an on-going struggle. Even when we follow all the cultural norms that lead others to high levels of success, we find ourselves with markedly different outcomes [24], [44]. This is because the disciplinary domain works to maintain societal structures from within. As Collins states, "If you can no longer keep Black women outside, then how can they best be regulated once they are inside?" [4, p. 280]. Within STEM, reports of unfair, and often cruel, treatment of undergraduate Black women underscore this point [9], [45].

Black women undergraduates also contend with institutional and departmental cultures that see them as "the other." This viewpoint expects Black women to assimilate into the dominant space,

assume the dominant ways of being, and subscribe to and operate in meritocracy and deficit model thinking to persist in STEM [46], [47], [48]. This false narrative of meritocracy results in undergraduate Black women in STEM struggling to manage the common challenges of college life, while also carrying the concern of how their actions appear through the culturally stereotypical lens of the "angry Black woman," "lazy welfare queen," or "promiscuous jezebel." This focus on the individual as the only one in control of her success or failure in STEM simply validates the existing STEM culture and teaches Black women that we, not the system, are inherently flawed [4].

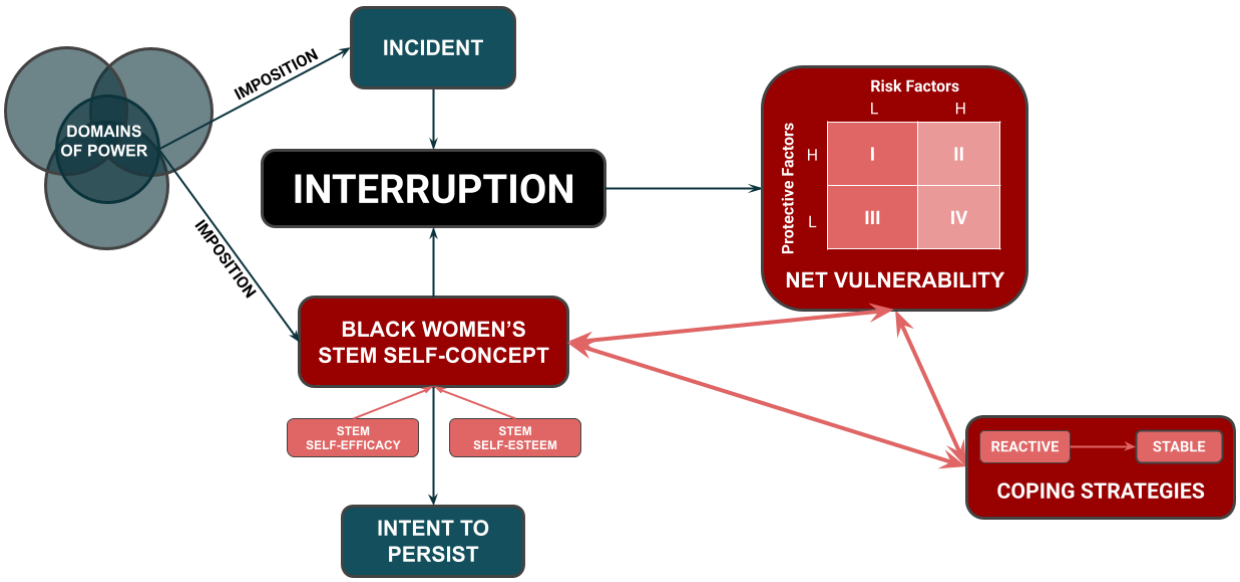

Figure 2. Model for Interruption of Black women in STEM

These domains (structural, disciplinary, and cultural) intersect in the interpersonal domain and show up as micro and macro-aggressions in the daily lives of Black women, shaping our self-concepts, as well as how we navigate dominant spaces [4], [16]. Our interruption model, shown in figure 2, highlights the role of these domains of power as the root cause of challenges for Black women in STEM, while simultaneously acknowledging that a Black woman's experience of the domains of power is inextricably linked to her STEM self-concept. According to our model, an interruption of Black women in STEM is an experience of an imposition of power, an incident, that causes a loss of momentum. This loss of momentum occurs because the incident either challenges a positive STEM self-concept or, conversely, reinforces a negative STEM self-concept. An individual's net vulnerability impacts how they choose to cope with an interruption and can be detrimental, which in turn influences their STEM self-concept, as well as their decision to persist [49], [50]. Next, we will further discuss three critical components of our framework: Black women's STEM self-concept, net vulnerability, and coping strategies.

Explanation of Framework for Interruption

Black women's STEM self-concept

Self-concept refers to how individuals perceive themselves, including their behaviors and abilities [51]. It doesn't just describe who we are but also acts as a source of motivation, driving our actions and decisions. Rogers believed that self-image, ideal self, and self-worth are the three main components of self-concept [52]. These three components of self are constantly evolving based on experiences throughout a person's life. As we seek to understand the role of Black women's STEM self-concept in their experience of interruption, we discuss two motivational forces in self-concept development as described by Gecas: self-efficacy and self-esteem [53].

Self-efficacy is grounded in the belief in our ability to influence outcomes. It involves a sense of agency—the understanding that we can control certain aspects of our lives while recognizing that other things are beyond our influence. For example, when we succeed at a task, we attribute the outcome to our own efforts, taking responsibility for what we can control. Conversely, when outcomes are beyond our control (e.g., external circumstances, and others' actions), we may not feel personally responsible for them. This balance between what we can change and what we cannot helps shape our motivation to engage with challenges and persist in the face of setbacks.

Microaggressions, such as being overlooked in class, excluded from group work, ignored in intellectual discussions, or having contributions dismissed as insignificant are common occurrences for Black women in STEM [17], [54]. Repeated exposure to these hostile environments can undermine Black women's STEM self-efficacy and motivation to persist, as the balance between what we can control and what we cannot tips and the veil of meritocracy is removed [55]. In addition, the coping strategies Black women in STEM employ to address microaggressions can, when cultural and structural forces remain unchanged, lead to negative mental health outcomes [56], [57].

Self-esteem is how much we value, or like, ourselves. When considering our self-esteem, we are motivated either by the need for self-enhancement—the desire to improve, grow, and gain recognition—or by self-maintenance, the drive to preserve and protect the current traits or status that contribute to our sense of identity. People with high self-esteem often seek to boost their sense of value, while others may focus on avoiding threats to their self-image. This desire can be a powerful motivator, influencing how individuals approach challenges, relationships, and opportunities.

Within STEM, Black women often encounter stereotype threat, which diminishes self-esteem by generating anxiety and stress related to their belonging in STEM [58], [59]. These stereotype threats weigh on Black women as they seek to be successful in their chosen STEM field. The challenges faced by Black women in STEM are not limited to the academic demands of the field, such as rigorous coursework, but also originate from navigating spaces where they are often the sole representatives of their gender and racial background. This can lead to experiences of being ignored or overlooked [18]. However, when explicitly made aware of stereotypes, Black women

often use this awareness as a source of motivation to resist the negative impacts on their self-esteem.

Applying these ideas of Black women's STEM self-concept to our framework, we understand the variety of inputs influencing how Black women see themselves within STEM. Through this lens, the behaviors, challenges, and motivations of Black women in STEM, when faced with an interruption, can be better understood, as well as their decision to persist or leave.

Net vulnerability

Our interruption framework suggests that the impact and response to an interruption depends on an individual's net vulnerability: identified risk factors combined with available protective factors. Net Vulnerability is taken from Spencer's Phenomenological Variant of Ecological Systems Theory (PVEST) framework [50]. Extensive descriptions of PVEST have been written [50], [60], but our framework focuses on this first component, which "consists of individual, family, and community characteristics that may serve as risk versus protective factors during an individual's development" [50, p. 847]. The importance of this balanced characterization of an individual's psychological state cannot be overstated, as it showcases that all individuals, no matter their circumstances, have a mixture of challenges and assets, and the choices made, when dealing with stressful events, are determined by a combination of these factors. Applied to our context of interruption, when faced with an interruption, an individual's net vulnerability can influence, positively or negatively, the coping strategies they use to respond to that interruption.

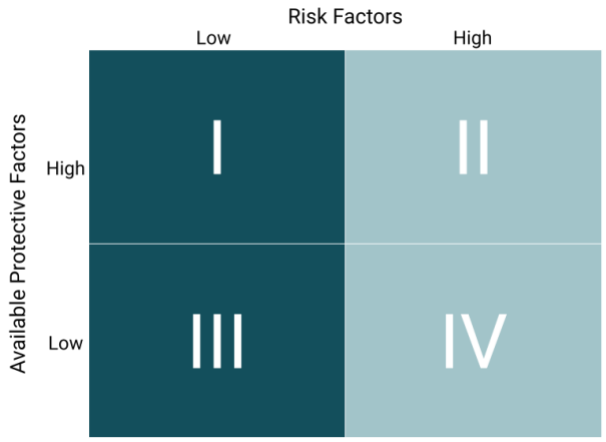

Figure 3 Net Vulnerability Matrix

Our model of net vulnerability (figure 3) uses a four-quadrant scheme to understand individual experiences of interruption. The vertical access groups individuals as having high or low levels of access to protective factors, while the horizontal access categorizes individuals as high or low risk. Those in quadrant I are the least vulnerable group, as they have high levels of available protective factors and low risk factors, while those in quadrant IV are the most vulnerable. We hypothesize that Black women in STEM fall into quadrants II and IV, due to the high level of risk factors that come with their racial and gender identities. It is, therefore, reasonable to assume

that individuals in these quadrants may demonstrate significantly different responses to interruptions, given the varying levels of stress and support that they experience.

This approach aligns with research, which has found that individuals, and specifically students, who perceive they have high access to support (protective factors) tend to use more effective coping strategies [61], [62], [63]. It therefore makes sense that when an individual perceives support as reliable and helpful, it can lessen the negative effects of stress and ultimately influence how they cope with an interruption.

Coping strategies

Coping is defined as the continuous thoughts and behaviors employed to manage stressors [64]. Although the fundamental need to cope is a natural part of life, the literature confirms that there are unique coping strategies used by Black women connected to our intersectional identities [58], [65], [66], [67], [68]. These specific strategies are often essential for addressing feelings of distress and inadequacy and ultimately act as protective shields in our lives [58], [69].

The frequency of interruptions, Black women's STEM self-concept, and the intensity of the interruption, as determined by net vulnerability, shape the selection of coping strategies used by Black women [70]. When faced with a new interruption, Black women employ what Spencer's PVEST framework refers to as "reactive coping responses," immediate, situation-specific strategies employed to manage stress in the moment [50]. The outcome of that coping strategy, in relation to the desired outcome, influences that woman's response when faced again with that interruption or one that is similar. Over time, as Black women repeatedly experience the same interruptions, these reactive coping responses contribute to the ever-changing STEM self-concept mentioned previously**,** as well as behavioral patterns that evolve into stable (productive or unproductive) coping strategies [60]. Therefore, as Black women experience repeated interruptions, what may have been a reactive coping response, in the beginning, can turn into a stable coping method over time.

Reactive and stable coping are both grounded in three fundamental processes: (1) a search for meaning in an interruption (negative stressor), (2) an attempt to regain a sense of mastery over an interruption, and (3) an effort to restore a positive sense of self after an interruption [71]. These processes provide an understanding of how Black women respond to interruptions and develop coping strategies over time.

The selection of reactive coping strategies involves two key steps: (1) evaluating whether the situation is harmful, threatening, or misaligned with one's STEM self-concept, and (2) identifying the strategy most likely to achieve the desired outcome [72]. This decision-making process forms the foundation for how Black women refine coping strategies over time to optimize outcomes of mastering the negative impact of the interruption and restoring a positive STEM self-concept [72]. As these strategies are employed—whether adaptive or maladaptive—those yielding favorable results are reinforced, internalized, and integrated (stable coping) into their STEM self-concept. This iterative process shapes immediate coping responses, informs the

development of stable coping strategies, impacts net vulnerability, and further influences both self-concept and the overall effectiveness of their coping mechanisms [60], [72].

Adaptive coping responses are constructive approaches to managing stress that promote resilience and problem-solving. Examples of adaptive coping responses for Black women in STEM may include engaging support systems and resistance activities and are generally considered protective factors that mitigate the adverse effects of interruptions [60], [66], [69], [73], [74]**.** In contrast, maladaptive coping responses are counterproductive responses that, while potentially helpful in the short term, are often associated with negative outcomes, including increased psychological distress and a detrimental impact on one's STEM self-concept over time [71], [73].

The interplay between net vulnerability and coping strategies (reactive and stable) is constantly shaped by the unique ways Black women experience stress and perceive the availability of support. These experiences of stress and perceived availability of support influence both the selection of coping mechanisms and their effectiveness in managing stress, i.e., making meaning of the interruption, mastering the interruption, and restoration of positive self-concept. In turn, the ways coping strategies are normalized inform how stress is perceived and experienced over time.

Although generalizations can be made about reactive coping strategies, their effectiveness depends on context, frequency, and the extent to which they influence or align with an individual's STEM self-concept [75]. For example, A common, unhealthy, or maladaptive coping strategy, often encouraged in higher education, advises Black women in STEM to focus on resilience and perseverance. On the surface, developing the ability to progress through challenging circumstances is noble. Unfortunately, implying that an individual can simply choose to persevere through trauma reinforces the "strong Black woman" stereotype, encourages the continued silence of Black women experiencing trauma, and allows the marginalizing societal structures to remain unchanged [49].

Stable coping strategies (productive and unproductive) develop over time as individuals repeatedly use reactive coping responses to address interruption [60], [72]. Productive, stable coping strategies, such as competency, self-efficacy, or leveraging support networks, can foster resilience and reinforce a positive STEM self-concept [60]. These strategies enable Black women to navigate structural barriers, maintain a sense of agency, and achieve academic and professional goals despite challenges. Conversely, unproductive stable coping strategies may result in negative STEM self-concept — attitudes of avoidance and internalization of negative stereotypes - self-imposed prove-it-again bias [76], [77], self-imposed perfectionism [78], and perpetuate feelings of inadequacy [60].

The cyclical and bidirectional relationship between stress responses, coping responses, and self-concept can lead to varied outcomes over time. Depending on the Black woman's self-concept, outcomes can include but are not limited to resistance, a sense of agency, positive familial and friend relationships, exiting STEM, dropping a STEM class, changing a STEM major, or

disengagement from STEM altogether [72].

On first review, it may appear that some interruptions are minor setbacks; however, their cumulative effects are far-reaching. As Black women in STEM repeatedly encounter interruptions, they develop context-specific reactive coping responses, which gradually evolve into stable coping strategies over time and significantly shape their STEM self-concept. Over time, these interruptions compound, causing Black women to fall further behind their peers and reinforcing societal inequities that remain difficult to overcome, regardless of degree completion.

Conclusion

Enhanced participation of Black women in STEM is of ethical imperative, and empowering individuals who would otherwise not be able to fully engage in STEM increases our national potential to advance science and solve real-world problems. However, about one-third of Black women depart from STEM as undergraduates [31]. It is, therefore, not surprising that the percentage of Black women earning bachelor's degrees in computer sciences, mathematics and statistics, and engineering has declined in the past twenty years [31]. This concern is further acknowledged by the National Science Foundation in their 2020 *STEM Education for the Future* report where the need for more diversity in STEM was highlighted as Priority I, Challenge 2. In particular, the report states:

> It is crucial that today's students represent all dimensions of America's diverse society to facilitate equity and inclusion, because today's students will become tomorrow's STEM faculty, workforce and innovators [79, p. 14].

To meet this challenge, we must go beyond funding to include interventions that disrupt the unique systems of oppression experienced by Black women in STEM. We must interrupt the interruptions.

Our proposed conceptual framework for interruption was designed to interrogate how repeated interruptions experienced by Black women in STEM disrupt their momentum and cause them to resort to coping strategies that often lead to unhealthy consequences. We believe Black women in STEM likely experience interruptions at a higher rate than their counterparts and that the cumulative effect of repeated interruptions can lead Black women to ultimately decide to exit STEM. This framework has the potential to serve as a guide to unpack many questions about the persistence and retention of Black women in STEM.

Although the framework was originally designed to better understand how interruption impacts Black women in STEM, we believe it can be applied in other contexts. The framework has gone through many iterations, and we continue to adjust it, as needed, to ensure its applicability to a range of audiences. We hope that as we continue to refine it, practitioners and researchers will seek ways to apply the framework to their specific population and context of focus.

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