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CHANGING THE FACE OF STEM: REVIEW OF LITERATURE ON THE ROLE OF MENTORS IN THE SUCCESS OF UNDERGRADUATE BLACK WOMEN IN STEM EDUCATION

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Abstract

The lack of ethnic and gender diversity in STEM undergraduate programs may lead to diversity and equity issues in STEM careers. However, some research suggests that mentoring influences the career trajectory of Black undergraduate women students in STEM. The investigation into these phenomena highlights suggestions for future research on mentoring Black undergraduate women in STEM. More recently, empirical research on mentoring among Black women have gained some momentum. Furthermore, with the increasing diversity and inclusivity demands from #ShutdownSTEM, in support of the Black Lives Matter movement, there is a focus on correcting barriers to access in STEM. Therefore, this conceptual paper reviews the literature on mentoring undergraduate Black women in STEM, effective mentoring best practices, and future research and policymaking suggestions.

Introduction

In 2017-2018, Black women of African descent earned only 2.9% of bachelor's degrees across science, technology, engineering, and math (STEM) fields (National Science Foundation, 2019a). Amid experiences of being ignored, marginalized, and isolated due to the lack of access to Black women peers and mentors (Charleston et al., 2014), there is a growing research interest in factors that predict the persistence of undergraduate Black women in STEM (Kerr et al., 2012; Perna et al., 2009). Several scholars have explored the success of Historically Black Colleges and Universities (HBCUs) in graduating Black students, particularly Black women, in STEM. Gasman and Nguyen's (2014) study broadly explored HBCUs' specific contributions to the success of Black students in STEM. They revealed four major themes: peers mentoring peers, undergraduate research experience, celebrating success in STEM, and same-gender and race faculty role models. These themes of mentorship permeate the HBCU STEM success literature (Gasman & Nguyen, 2014; Meador, 2018; Palmer et al., 2011). However, little research has focused explicitly on the impact of mentoring on STEM success based on race and gender. In concentrating on mentorship among undergraduate Black women in STEM, this paper extends research on mentorship of Black women students in STEM by applying an intersectional lens to the understudied domain of the impact of mentoring on the academic success of Black undergraduate women in STEM.

Given previous research, **s**cholars point to the need for more race and gender-based (RGB) mentoring for Black women STEM students (McGee & Bentley, 2017). Mentoring is the developmental relationship between a more experienced individual (mentor) and a less experienced individual. The mentor supports personal and professional development (Crisp & Cruz, 2009; Eby et al., 2007). Past research has shown that mentoring, especially same race and gender-based mentoring, is seen as an effective method to recruit and retain women and people

of color in STEM education and careers (Hernandez et al., 2017). Furthermore, it is argued that establishing mentor relationships can help Black women students resist assumptions about Black women's experiences in STEM (Sanchez et al., 2020). Although targeted efforts are designed to increase Black women students' continued participation in STEM (Charleston et al., 2014), retaining and matriculating undergraduate Black women in STEM continues to be a challenge. Thus, we present a conceptual paper that gathers research on the characteristics and best practices on mentoring undergraduate Black women in STEM, which has implications for broadening the participation of Black women in STEM education and careers.

Theoretical Perspectives in Mentoring Undergraduate Black Women in STEM

There are several theoretical perspectives in the literature shown to be effective in mentoring STEM students. Traditional mentoring theories include hierarchical mentoring, where faculty mentor students and students mentor others, usually their peers (Wilson et al., 2012). This model focuses on the reciprocal responsibility of each student to reinforce positive and successful strategies they learned to their peers. In addition, peer mentoring models are often seen as a "professional, working alliance" (p. 2) in which students work, learn, and support each other (Rockinson-Szapkiw, Wendt, & Stephen, 2021). Variations of this model are beneficial among racial and ethnic minority women, particularly those persisting in STEM (Graham and McClain, 2019; Ireland et al., 2018; Mondisa, 2018).

Examining more culturally relevant and responsive mentoring models, a prominent theory used when exploring mentoring among Black women in STEM education is Black Feminist Thought (BFT). BFT is a theoretical framework that centers on the collective experiences and standpoints for Black women (Collins, 1991). The main tenets of Black feminist thought to focus on 1) the importance of Black women's self-definition and self-valuation, 2) Black women's identities must be viewed through interlocking nature of race, gender, and class oppression, among other identities, through intersectionality, and 3) the importance of recognizing Black women's shared culture to better understand their daily lives within institutions, such as family, church, and academia. As such, BFT gives a voice to Black women mentoring relationships because the mentor and mentee often share similar experiences based on their intersectional race and gender identities (Collins, 1991). Specifically, intersectionality is a framework to explain the interlocking systems of privilege and oppression relative to social identities such as race, gender, class, and sexual orientation (Crenshaw, 1991). Using an intersectional lens, it addresses the double marginalization of being Black and a woman. BFT empowers Black women within the context of social justice based on their intersecting experiences of oppression (Collins, 2000). BFT urges educational leaders to understand that Black women have experiences that women who are "members of the majority group do not experience" (Williams et al., 2005, p. 183).

BFT, viewed through an intersectional framework, is critical to understanding how mentorship leads to success among Black women's persistence in STEM. As such, Rasheem et al. (2018) utilized the BFT to capture the essence of mentorship, experiences, and the voices of Black women in STEM graduate programs. One of the study's significant findings was the high importance of having a mentor who has a shared viewpoint and identity who could relate to their journey and assist in navigating the academy. Borum and Walker (2012) also used BFT to explore Black women's post-secondary experiences, mainly STEM. Mentoring was a critical factor in the retention and success of the Black women in the study. Additionally, participants vocalized the positive impact of mentoring on their personal and professional lives and noted that

mentoring consisted of structural and informal mentorship through academic, familial, and churches. In summary, this research highlights the significance of using BFT to understand the mentoring needs and experiences of Black undergraduate women in STEM.

Literature Review

Mentoring undergraduate Black women in STEM has led to the success and persistence of Black women obtaining STEM degrees. Previous research on mentoring in STEM for undergraduate students from underrepresented groups, such as Black women, will be discussed. First, we will review pertinent research in this area, discuss limitations in the study, and provide suggestions for future research. Then, we will discuss the implications of this research for practice and policy.

Faculty Mentoring and STEM Success of Black Women

A rigorous K-12 preparation in STEM courses, high expectations of teachers (elementary & secondary), strong teacher/student relationships, and volunteering experiences are all factors that support the STEM success of students of color (Palmer, Maramba, & Dancy, 2011). Key among them is faculty mentoring, which is central to the success of STEM majors (Hunter et al. 2007; Munawar 2015, National Science Foundation, 2019b), especially the recruitment and retention of Black women STEM majors (Amaya et al., 2018; Bonous-Hammarth, 2000; Hurtado et al., 2008). One type of mentorship that is critical to the persistence of Black women in STEM is faculty and professional mentoring relationships. Previous research suggests that faculty mentors provide support across three dimensions: psychosocial support (counseling, encouragement, and role modeling), instrumental support (coaching and providing opportunities for professional advancement such as research experience), and co-authoring experiences (collaborative presentations and research publications; Eby et al., 2013; Jacobi, 1991).

Furthermore, faculty who guide with research and meaningful scholarly activity becomes a powerful instructional resource (National Science Foundation, 2019b). Grandy (1998) emphasized that the support students of color, including Black women, receive from faculty impacts their grades and positively relates to their commitment to STEM. Bonous-Hammarth (2000) explained that students of color, including Black women, who receive mentoring in college are more likely to succeed in STEM education. Research on the advantages of faculty mentoring of Black students in STEM often examines outcomes at the aggregate level (e.g., Black women and men; Reddick, 2011), while research on students of color in STEM is limited and does not include the intersection of race and gender (Linn et al., 2015). Understanding the successful qualities in faculty mentoring of Black undergraduate women's success in STEM is an important start to theorize about the impact of faculty mentoring on students who experience double marginalization in STEM (e.g., women of color).

Faculty Mentoring Through Undergraduate Research Experiences

Researchers regard undergraduate research experiences (UREs) as a critical element of recruitment and retention of Black Americans, especially Black women, in STEM fields (Amaya et al., 2018; Barlow & Villarejo, 2004; Hurtado et al. 2008; Kardash, 2000). In addition, the myriad of UREs connects STEM majors with professors beyond the undergraduate level (Palmer & Gasman, 2008). Specifically, it creates a passion for scholarship and inspiration among Black women undergrads from exposure to research opportunities (Perna et al., 2009). Furthermore, UREs increase student engagement, access to merit-based scholarships (Harger & Fresquez, 2016; Kuh et al., 2010), provide opportunities that increase interest in graduate school (Graham et al., 2013), and is associated with higher persistence in STEM degree programs (Christie et al.,

2017). In addition, evidence highlights an increase in active learning, practical skills, problem-solving, communication, and information synthesis (Haeger et al., 2016; Hunter et al., 2007) because of research experiences. Furthermore, undergraduate research experiences increase learning (Linn, Palmer, Baranger, Gerard & Stone, 2015) and positively impact the STEM career pipeline trajectory.

Yet, little research has explicitly explored the significance of undergraduate research experiences among women of color in STEM. Espinosa (2011) administered a survey to examine the effect of pre-college characteristics, college experiences, and institutional setting on the persistence of undergraduate women of color in STEM majors. The results showed that women of color who persisted in STEM did the following: participated in undergraduate research programs, engaged with peers to discuss course STEM content, was involved in STEM-related student organizations, had ambitions, attended private colleges, and attended institutions with a diverse community of STEM students. However, developing a science identity was of the most importance. This quantitative study is original, as it addressed an area of research exploring factors that led to STEM success among women of color (Espinosa, 2011). However, individual data exploring these factors across ethnics groups of women of color was missing. Considering this, STEM organizations and scholars interested in the impact of undergraduate experiences, particularly among Black women, may benefit from a longitudinal study quantitatively exploring the significance of UREs and their persistent interest in STEM.

Significance of Same Race and Gender Faculty Mentorship for Black Women in STEM

Along with research on the positive impact of faculty mentoring on STEM majors, there is a growing body of knowledge on the power of Black women STEM majors' experiences with Black faculty who share the same gender and race (Clewell et al., 2010). Diversity among STEM faculty has been shown to decrease discrimination, stereotyping and provides a counternarrative to negative images of Black women in STEM fields (Perna et al., 2009). Black faculty are also more inclined to be respectful of the intellect and learning process of Black STEM majors (Clewell et al., 2010). In addition, Black faculty provide students with many advantages, including strategies for coping with racism and sexism in the STEM pipeline (Cheatham & Phelps, 1995; Colbeck et al., 2001). Faculty of color increase students' confidence (Cheatham & Phelps, 1995; Hurtado et al., 2008). They also increase students' desire to pursue advanced degrees in the STEM fields (Cheatham & Phelps, 1995). Students who attended a predominantly white institution (PWI) discussed that they sought out Black professional mentors because there were only one or no Black professors in their department (Sanchez et al., 2020).

More specifically, it is argued that the promotion of belonging in STEM environments for Black undergraduate women may be influenced by Black women scientist role models (Johnson et al., 2019). Johnson and colleagues (2019) explored identity in role models among Black undergraduate women in STEM. Researchers found that participants reported more significant perceived similarity and sense of belonging with Black women professors than White men professors. Moreover, Black undergraduate STEM women attending a women's HBCU who had a mentor received mentorship in their department, and their mentors were individuals they admired (Jackson and Winfield, 2014). Undergraduate Black women also found mentor matching by race and having a mentor who understands their experiences as professionals in their field to be more important relative to their male peers (Blake-Beard et al., 2011). It is theorized that Black women mentors in STEM adds visibility to Black women in STEM and empowers undergraduate Black women to persist in the field (Jackson and Winfield, 2014). This

research points to the need for the same race and race and gender mentorship to promote the persistence and success of undergraduate Black women in STEM. Yet, more quantitative research is needed to examine characteristics of a successful same race and gender mentor that promotes persistence in STEM for undergraduate Black women. Also, higher education STEM programs may consider making it a priority to reevaluate their organization's culture to ensure race and gender-based diversity in their STEM department faculty.

Faculty Mentoring at HBCUs

For example, HBCUs have made proactive and intentional efforts to recruit and retain diverse faculty (Taylor et al., 2010) and provide institutional support for Black STEM majors (Seymour & Hewitt, 1997). In addition, HBCUs implement structures supporting positive peer relationships (Fleming, 1984), encourage faculty and administrators to focus institutional efforts on promoting student success (Gary, 2010), link STEM curriculum to African culture (Riley, 2003), and provide culturally responsive curriculum (Busch-Vishniac & Jarosz, 2004). More specifically, undergraduate STEM programs at women's HBCUs provide support and close student-faculty interactions. Perna et al. (2009) conducted a case study on the success of a women's HBCU in the recruitment and retention of Black undergraduates in STEM. The authors reported cultural factors that led to the academic success of the Black women in STEM: faculty's belief that their students could achieve academic success in STEM and innovative instructional approaches that encouraged academic attainment. Finally, the undergraduate Black women stated that faculty encouraged their academic success through accessibility (Perna et al., 2009). In all, most of the faculty mentorship that Black undergraduate women received in STEM, specifically at HBCUs, was not packaged in a formal mentoring program (Jackson and Winfield, 2014). Although researchers indicate that women's HBCUs are particularly effective at addressing barriers for undergraduate Black women in STEM (Perna et al., 2009; Jackson and Winfield, 2014), little quantitative research has explored the role faculty mentoring plays in influencing Black women's success in the STEM fields. The literature review provided an overview of some successful mentoring models between faculty and undergraduate Black women in STEM, with regards to faculty mentoring of undergraduate research experiences, same race and gender-based mentoring, and the success of faculty mentoring at women's HBCUs. Since many of these studies were qualitative or conceptual papers, utilizing quantitative or mixed methods studies may also be necessary for generalizing findings and contributing to a better understanding of specific factors of faculty mentoring that lead to the persistence of Black undergraduate women who go on to obtain advanced degrees in STEM or pursue careers in STEM.

Peer Mentoring

Peer mentoring is another factor that has shown success in the development of STEM talent for Black women. Peer mentoring of potential Black women undergraduate STEM majors has also been identified as an effective recruitment and retention mechanism, supporting women of color's interests, self-efficacy, and persistence in STEM (Rockinson-Szapkiw & Wendt, 2020). Peer support provides "communal success" (Maton et al., 2000) and social networks (Palmer et al., 2011) for STEM majors, and broadly, opportunities for career strategizing, psychosocial support, and friendship (Thomas et al., 2005). Gasman (2013) recommends that institutions promote peer support as a part of their institutional ethos. Although many Black students at PWIs viewed themselves as adversarial or competitive with peers (Seymour & Hewitt, 1997; Zhao & Kuh, 2005), it was reported that peer mentoring at HBCUs provided benefits to STEM majors (Perna et al., 2009).

Black undergraduate women attending an HBCU described that their peer support/mentoring resulted in the sense of sisterhood (Perna et al., 2009). Moreover, researchers also found that there are benefits to the peer mentoring experience for the peer mentors. For example, Rockinson-Szapkiw et al. (2020) explored peer mentors' STEM self-efficacy beliefs, interests, skills, and persistence in STEM by using a multisite case study design at two HBCUs. They found that experience in the peer mentoring process increased mentors' self-efficacy, career interest, perceived mentoring skill development, and their intent to persist in STEM. In all, though researchers indicate that HBCUs and women's HBCUs are particularly effective at addressing peer mentoring (Perna et al., 2009), further research is needed regarding the longitudinal impact of peer mentoring on the recruitment and attainment of undergraduate Black women in STEM fields.

Mentoring: From Theory to Current Practices and Policies

It is generally understood that STEM education is of great importance to discovery and advancement, nationally and internationally. It is critical for the United States to attract, train, and retain a diverse population of STEM professionals to advance scientific literacy and innovation. It is an even greater need to retain students from historically marginalized backgrounds, such as Black women (Wilson & King, 2016), in STEM. The low number of Black women with degrees in some STEM fields is distressing. For example, fewer than 100 Black women in the US have obtained a Ph.D. in physics (Authors, 2020). Unfortunately, there have traditionally been high attrition rates among STEM majors, in general, and among Black women specifically. A foundational question to be addressed is whether Black undergraduate women choose not to enter STEM majors, or are they not persisting in STEM? Because of the abysmal numbers of Black women in STEM, many universities set recruitment and retention goals for this population. A small but growing body of literature supports the development of focused prevention and intervention programs (Wilson et al., 2012).

The benefits of these programs on the academic and professional success of Black women are documented in the literature (e.g., Sanchez et al., 2019). While many mentoring programs focus solely on academic outcomes, it is essential to embrace the idea that successful mentoring of Black women should also include personal development and psychosocial elements for growth. Authors (2020) suggested that culturally responsive programs can assist with the persistence and retention of Black women in STEM by understanding *why* they are persevering, despite many of the challenges they face. Fries-Britt and Holmes (2012) found a strong connection between the role of science and the broader values that Black women held. Culturally specific evidence such as this may serve as the much-needed point of entry to spark a radical cultural shift in academia, especially in STEM.

Much has been written about the theoretical underpinnings of successful STEM programs, and mentoring is at the core consistently. One suggestion to help close the gap between theory, practice, and policy is to invest in informal mentoring programs. Many departments have faculty who are informally supporting Black undergraduate women in STEM; however, more formalized training and mentoring programs that are structured and *funded* are needed. For example, summer pre-college programs have been found to enhance the retention and persistence of students of color, particularly Black women, in STEM education and help develop critical relationships and provide income for STEM majors (Perna et al., 2009). Additionally, investing in mentoring programs that are not strictly based on laboratory settings and relationships may benefit Black women (Zaniewski and Reinholz, 2016). This paper

indicates that mentoring frameworks differ significantly from hierarchical to peer, academic to psychosocial focused, and race and gender-based. Crisp et al. (2017) noted that a comprehensive framework acknowledges the intersection between students and their educational context. Students do not operate in a bubble without cultural and contextual influences, and those variables that may hinder or enhance a students' success should be addressed.

In a study by Griffin (2013), findings revealed that interactions between same race mentors and students were successful because there was a unique commitment to the students' success. Students experienced a sense of comfort and closeness to these faculty (Crisp et al., 2017). Mentoring programs should also include standard mentoring components such as training to increase competencies and skills and include opportunities for self-reflection and components of faculty support (Rockinson-Szaphkiw & Wendt, 2020). There needs to be more focus on the holistic development of Black women in STEM. We know that mentoring relationships are essential for Black women and all minoritized populations in STEM; however, we know less about the specific types of activities that produce the most favorable outcomes. One way of addressing this issue is to fund more research surrounding the success of HBCU faculty mentoring Black women in STEM. HBCUs have successfully attracted Black STEM faculty and supported Black women in STEM (Kendricks et al., 2013). Researchers at other minority-serving institutions (MSIs) and PWIs should engage in a mutually beneficial partnership with HBCUs to explore the mentoring strategies and frameworks.

Additionally, it would be essential to develop potential pipeline programs for Black women interested in attending graduate and professional school at an MSI or PWI. There is a documented storage of Black women faculty mentors in STEM fields, which is due, in part, to the underrepresentation of Black women in STEM majors. (Stoeger et al., 2019). If the number of Black women STEM majors does not increase, the number of Black women in STEM fields will not increase.

Conclusion

In closing, while it is true that students from historically marginalized communities may often need more resources and support to be successful in college, it is also true that tailoring mentoring programs to fit the needs of the population is more beneficial than a 'one-size-fits-all' framework. The empirical study of successfully mentoring Black undergraduate women in STEM can increase the pipeline of more Black women pursuing advanced STEM degrees and STEM careers. Black women may need different resources and support than their Black male and White counterparts, not because of a deficit of knowledge or intellect, but because of the double jeopardy that they face by being both Black and woman in a White-male dominated field whose culture has been "characterized as insular, masculine, and white male-dominated" (Joseph, 2014, p.2). Given this, it should not be startling that Black women are underrepresented as STEM majors in college and the professional workforce. This paper calls for financial resources to be devoted to confronting gendered racism (racism and sexism) in STEM by supporting the recruitment, retention, and persistence of Black women and other women of color in STEM.

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