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Increasing the Persistence of Black Women in STEM (WiSTEM) by Implementing and Sustaining a Successful Cohort Model for First-Year Undergraduate Women at an HBCU

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Celebrated for her TedxTalk - Creating diverse and equitable initiatives in data science, Tiffany Oliver is an Associate Professor and Chair of the Biology Department at Spelman College (Atlanta, GA). Dr. Oliver is a Carnegie and Rockefeller Distinguished Research Scholar and received her Ph.D. in Genetics and Molecular Biology from Emory University. Her research, funded by the Department of Defense, aims to understand how near infrared light can be used to heal wounds. Outside of conducting research, Dr. Oliver is passionate about increasing diversity in STEM. She currently directs several undergraduate research programs which provide collegiate black women with the training and expertise needed to acquire jobs in the field of data science. Her passion resides in mentoring and sustaining minority students in STEM (science, technology, engineering, and mathematics), by studying and evaluating the best practices for people of color who are interested in pursuing careers in research and medicine.

Dr. Oliver presents nationally and internationally to student groups, major scientific societies, faculty other interest groups on the experiences of minority students in STEM disciplines and how to increase their retention in the sciences. Her goal is to change the narrative around ethnic minority students in STEM disciplines by improving their scientific experiences.

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Pamela Leggett-Robinson is the CEO and Executive Director for PLR Consulting in Atlanta, GA. PLR Consulting is a boutique Program Development, Management, and Evaluation firm that works with organizations and institutions that seeks to address multi-faceted obstacles confronting both historically and presently marginalized groups in STEM environments as well as optimize current STEM programs through management and evaluation. Dr. Leggett-Robinson has more than 15 years of higher education experience which includes STEM academic and student success/support programming, strategic planning, data analytics, and program evaluation. As a PI, she has garnered funds in excess of $3 million dollars from both NIH and NSF for broadening participation in STEM Undergraduate Education and as an Evaluator has worked on large projects with NSF (Big Data, BioGraph), Google CS-ER, and DOD STEM Student Success. Her distinguished record of STEM programmatic success (at HBCUs and PWIs) is well documented in publications and presentations. Dr. Leggett-Robinson's latest publications, "Demystifying Promotion & Tenure: A resource for Black Women" and "Overcoming Barriers for Women of Color in STEM" are resources to assist Black women along their STEM journey. She currently distributes a bi-monthly Overcoming Barriers Newsletter to Women of Color STEM faculty. Dr. Leggett-Robinson holds a Ph.D. in Physical Organic Chemistry from Georgia State University and is a Certified Associate of Project Management.

TITLE

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ABSTRACT

Despite initiatives, policies, and procedures to increase the representation of Black women in STEM, they remain largely underrepresented, especially in mathematics, computer science, and engineering. This study describes the long-term success of the Women in STEM (WiSTEM) Program, a pre-freshman summer bridge and academic-year experience for incoming first-year students majoring in STEM disciplines. The program has had twelve cohorts over the last fifteen years and has served over 235 women. Ninety percent of WiSTEM participants graduate from college and more than seventy percent obtain their degree in a STEM discipline. This represents a marked increase from the national and College STEM retention rates of 43 and 45 percent, respectively. Many of these students have received or are pursuing advanced degrees in STEM. Our motivation for creating WiSTEM is the observation that Black women are underrepresented in STEM for a variety of reasons that include (1) anxiety pertaining to mathematics and computing (2) a lack of exposure to STEM disciplines and tangential careers (3) a lack of exposure to culturally responsive pedagogy, and (4) a lack of communities of support.

Key Words - STEM Identity, Sense of Belonging, Persistence, Community, Self Awareness

INTRODUCTION AND PROBLEM STATEMENT

Many institutions of higher education in the US do not reflect the racial and ethnic diversity of our nation amongst its degree recipients. Clearly, we must acknowledge the barriers to STEM education for individuals underrepresented in these disciplines and develop interventions to mitigate them [1]–[3]. Racial/ethnic minority students often face stigmatizing experiences, such as discrimination, especially at primarily white institutions [4]. This is also the case for women underrepresented in STEM fields [5], [6]. These experiences adversely impact students' social and academic experience [4] and can lead to a lack of connectedness and community among students in their academic setting [7].

Racial and ethnic minority students also experience stereotype threat, a phenomenon that occurs when there is the opportunity or perceived opportunity for an individual to satisfy or confirm a negative stereotype of a group of which he/she is a member [7]. Various studies have shown that stereotype threat negatively affects students' academic performance [8]–[10]. When stereotype threat is experienced repeatedly,

students can respond by de-identifying with their academic pursuits. As a result, they may minimize attributes and behaviors necessary for their success [7], [11]. This can also lead to students de-identifying with careers in scientific disciplines. Students underrepresented in STEM fields also experience more offenses, such as microaggressions from their administrators, their professors, and peers. Microaggressions exist in the form of either subtle or blatant statements or actions that intentionally or unintentionally communicate devaluing messages about a particular group of people [12], [13]. Students that experience microaggressions may feel isolated, which can negatively affect their academic performance and matriculation in STEM disciplines. Other barriers to diversity in STEM disciplines include systemic racism, defined as institutional, historical and/or cultural practices that put one social or ethnic group in a position to succeed, while simultaneously putting another group at a disadvantage in such a way that leads to the development of disparities over time. Systemic racism in academics promotes exclusion, the lack of environmental support [14], and implicit bias [15], which all contribute to racial/ethnic disparities in the sciences.

Black women face unique challenges in STEM because they deal with both sexism and racism as they navigate their career and educational journeys. This paper highlights the success of a STEM program at an all-women's historically Black college that was designed to create an affirming and supportive environment for Black women pursuing degrees in the STEM disciplines. All program participants identify as Black women and identify by the pronoun she/her. The key markers of the program's success include (1) fostering college preparedness by encouraging good habits (developing strategies for studying and time management), (2) building self-confidence in their academic abilities (creating a safe and affirming learning environment with supportive faculty, engaging in real problems of relevance to them), (3) embracing their identities as Black women in STEM (dealing with imposter syndrome, providing role models that reflect their identities), and (4) developing a community of women that support one another. We believe these markers represent transferable actions that can be implemented to improve the retention of minority undergraduates at other institutions. The paper is organized into the following sections. The background introduces the project framework. The next section provides an overview of the implementation of the program, followed by methodology and results. The last section presents a discussion of results and concluding thoughts.

BACKGROUND

Identity and Belonging

Self-perceptions regarding academic competence are framed by personal and collective identities. Each student has many such identities—racial, ethnic, socioeconomic, professional, sexual/gender, and family. Students' positive

identification with their discipline can enhance academic engagement and belongingness and prove to be a great source of encouragement. However, more commonly the opposite is true, especially for non-traditional and marginalized STEM students. These students often experience challenges such as isolation, invisibility, discrimination, and a sense of not belonging and disconnectedness from external social and cultural networks [16]. Belonging to valued social or cultural groups is a fundamental human need and a sense of inclusion is particularly important for Black women in STEM when stereotypes imply that they might be unsuited to certain settings, such as rigorous academic classes [9]–[11]. Feeling a sense of belonging and acceptance by others in STEM (faculty and peers) is crucial to the intent to persist in STEM for these STEM students[12].

STEM identity is a reflection of how one understands and positions oneself within the STEM culture and is often defined as the composition of self-views that emerge from socialization and culturalization. Settings (communities) have the power to influence, create expectations, and influence decisions regarding STEM persistence.

Culturally Relevant Pedagogy and Persistence in STEM Disciplines

Culturally Relevant Pedagogy (CRP) is an approach to teaching that recognizes and values the cultural experiences and identities of students and incorporates these experiences into the curriculum and teaching practices [17]. This approach has been shown to be particularly effective in increasing the retention of underrepresented groups in STEM fields, including women[18].

One reason why CRP is important in STEM education is that it helps to address the cultural and social barriers that can prevent students from engaging in STEM disciplines. For example, students from marginalized communities may not see themselves represented in STEM fields or may not have access to the resources and support needed to succeed in these fields. By incorporating the experiences and perspectives of these students into the curriculum, CRP can help to create a more inclusive and welcoming learning environment that fosters student engagement and success[19].

In addition to addressing cultural and social barriers, CRP can also increase the relevance and meaningfulness of STEM education for students. When students see their own experiences and perspectives reflected in the curriculum, they are more likely to feel a sense of connection to the material and to see the value of STEM disciplines in their lives [20]. This increased relevance can help to motivate students and increase their persistence in STEM fields. However, while CRP has been shown to be effective in increasing retention in STEM fields, its implementation can be challenging. Educators need to be trained and supported in the use of CRP and may need to make significant changes to their teaching practices and curriculum[21]. Furthermore, the integration of CRP into STEM education may require institutional

support, including the allocation of resources and the development of policies that support this approach.

Program Description

The WiSTEM program provides academic support in mathematics and computer programming, gives opportunities for students to practice mathematics and programming on real-world project modules that have societal and cultural relevance, provides a cohort experience with other like-minded individuals, and offers a safe space for students to tackle issues they are likely to confront as a marginalized group in STEM. The program contains a summer bridge experience and academic-year learning community for students majoring in the physical sciences, environmental science, mathematics, computer science, and engineering. WiSTEM uses evidence-based practices that increase persistence in STEM like incorporating multiple forms of support such as mentorship and peer help, providing early exposure to university environments and faculty [22], [23], and adopting effective teaching strategies to help students learn more effectively [24], [25]. In addition to these proven strategies, the WiSTEM program includes CRP in the project modules and coursework and provides a safe space for students to talk about barriers to persistence that are specific to Black women in STEM.

Selection of Students

The WiSTEM program is open to all accepted first-year students who have identified STEM as their major. Students in chemistry, computer science, engineering, environmental science, mathematics, and physics get priority given the relatively low numbers of Black women who graduate with degrees in these disciplines. Selection into the program is competitive, but high school GPA and standardized test scores (not required) are given lower priority than the students' motivation for choosing a STEM major. Student motivation is determined by a combination of their response to an essay about why they choose STEM and other indicators like, number of years of high school mathematics and science courses (calculus is not required), and co-curricular or extra-curricular activities that are STEM focused (STEM clubs, programs, competitions, etc.).

WiSTEM Summer Bridge Program

The summer bridge program takes place for six weeks from early June through late July. The components of the summer program are (1) credit-bearing courses in math and programming,(2) an enrichment series that focuses on building competencies for college readiness and STEM identity, (3) hands-on project modules with real-world applications, and (4) a mandatory study hall.

1. Credit-Bearing Courses with Support:

Students take credit-bearing courses in python programming and mathematics. These courses were chosen because they are foundational to most of the STEM disciplines. In fact, readiness for calculus in the first year of college is a predictor of persistence and on-time degree completion in STEM [26], [27]. Supplemental Instructors (SIs) support the courses. SIs are undergraduate peers selected by the faculty member who teaches the course. They assist with grading and instruction and facilitate group study sessions. They also provide individualized tutoring to students who have trouble in a course. All students take the python programming course and are placed into mathematics, either precalculus or differential calculus, based on

their performance on a math placement assessment. Students are given the option to accept or decline the grades for the summer courses. There is no penalty for declining a grade. Ultimately, our goal is to build students' confidence and facility with these courses.

2. Enrichment Series

The enrichment series includes training on college readiness (study skills, time management, self-advocacy), professional readiness (resume' writing, technical writing, presentation skills), science identity and community (belonging, Black female role models, peer-mentoring, advocacy for others), and dealing with issues unique to Black women and other underrepresented groups in STEM (imposter syndrome, microaggressions, isolation). The enrichment series is a unique part of the WiSTEM program that helps students gain confidence and awareness of their place in STEM. The series uses a combination of texts, for example Bell Hooks essay "Loving Blackness as Political Resistance"; speakers who are Black women mentors and role models in STEM; and dialogues about overcoming barriers to their progress in STEM. The enrichment series has a particular focus on building a community of support among the cohort participants that is sustainable beyond the program.

3. Applied Project Modules

The project modules give students an early introduction to research through work on real-world problems. The module topics are designed by faculty or industry partners who facilitate learning through group work, discussion, and projects. The project modules include topics that are culturally relevant and/or socially responsive like machine learning, SIR (susceptible, infectious, recovered) models of COVID-19, cosmetic chemistry, and the physics of hair, to name a few. The project module on machine learning dealt with how poorly trained models can lead to biased results that can marginalize underrepresented groups like the failure of face recognition systems to recognize people of color. The module on the physics of hair used stress/strain

tests to determine how curly textured hair, typical of African populations, is impacted by chemical relaxers and hair coloring products. The project modules use CRP to make the projects more relevant to the students.

4. Study Hall:

Students are required to participate in a mandatory evening study hall on Monday through Thursday and on Sunday. The study hall helps students establish a regular study routine and practice good study habits like studying in groups, studying in a location separate from their rooms, and studying regardless of whether there are pending assessments or assignments that are due. The study hall is managed by the SIs who are available to do both individual and group study. We have found that the study hall helps the cohort to coalesce. The study groups are maintained during the academic year.

WiSTEM Academic Year Program

Students who participate in the summer bridge experience automatically become part of the WISTEM Living and Learning Community (LLC). The students receive academic advising from dedicated program staff, enrollment in common sections of many first- year courses including a seminar course for first-year students that focuses on college readiness. The academic year program maintains the cohesiveness of the cohort, encourages continued group study, and helps cement the relationship of the group beyond the first year.

Program staff also help the students identify internship and/or research experiences appropriate for their major and interests. Many students use the experience from the summer project module to bolster their applications for other research programs. In particular, a significant number of WiSTEM students participate in other undergraduate research programs and eventually enter graduate programs in STEM.

Participants

Surveys of WiSTEM participants (n=110) who were accepted first-year students, majoring in STEM were reviewed. Survey results were available for seven cohorts of WiSTEM participants for years 2007 through 2009 and years 2019 – 2022. STEM majors were categorized into three groups: science & math (48%), technology (11%), and engineering (41%). The science & math category included double majors, natural and physical sciences, economics, and psychology. The technology category consisted of computer science majors and the engineering category included those planning to participate in the Dual Degree Engineering program.

Approximately 10% of WiSTEM participants changed their major after participating in the program. However, the change in major was between STEM disciplines, i.e., biology to math or math to mechanical engineering. Resulting in 100% of the participants pursuing a STEM major in the Fall semester following the program. An evaluation was conducted to measure program success.

Data Collection

During their tenure in the WiSTEM program, participants were asked to complete pre/post surveys and focus groups to determine their reactions to and perceived outcomes of various student support activities. Surveys probed psychosocial constructs related to student persistence and success:

1. Comfort with math & science - Previous research on math anxiety has shown that it is a multidimensional psychological construct that involves complex factors, such as feelings of pressure, performance inadequacy, and test anxiety. The mathematics anxiety measure is intended to assess the feelings of dread and nervousness associated with math [28]. Reduction in math and math application anxiety are associated with interest and persistence in STEM fields.

2. Awareness & Exposure to STEM Careers - Career path is defined as the professional endpoint the student envisioned themselves in after obtaining a postgraduate degree. Career development theory explains that students' career path decisions are determined by exposure, family, school, community, and social factors. The navigation process involves students' perceptions of what the preparations and rewards for the career entail. [29], [30]. Example: "I am interested in pursuing a career that uses STEM."

3. Research and Scientific Skills - Research experiences are effective avenues for allowing students to apply theoretical concepts learned in class. These experiences have been shown to impact student retention as well as influence students' decision to persist in and pursue STEM careers. Example, "Participating in research helped me make a commitment to pursue scientific research opportunities."

4. Community Belonging - A sense of belonging with STEM contributes to student pursuit of STEM careers. Example, "I can see myself in a STEM career."

5. Intent to persist - Student intention to persist is highly indicative of actual persistence. Intent to persist can be examined in a temporal manner, looking at short-term, degree attainment, and long-term commitment [31]. Example, "I intend to attend graduate school in STEM."

6. Self Awareness - Self Awareness represents the extent to which one can identify and articulate personal values and professional values, accurately assess strengths and limitations, and view challenges with a growth mindset. Self-awareness plays a critical role in how students learn and develop as STEM professionals [32].

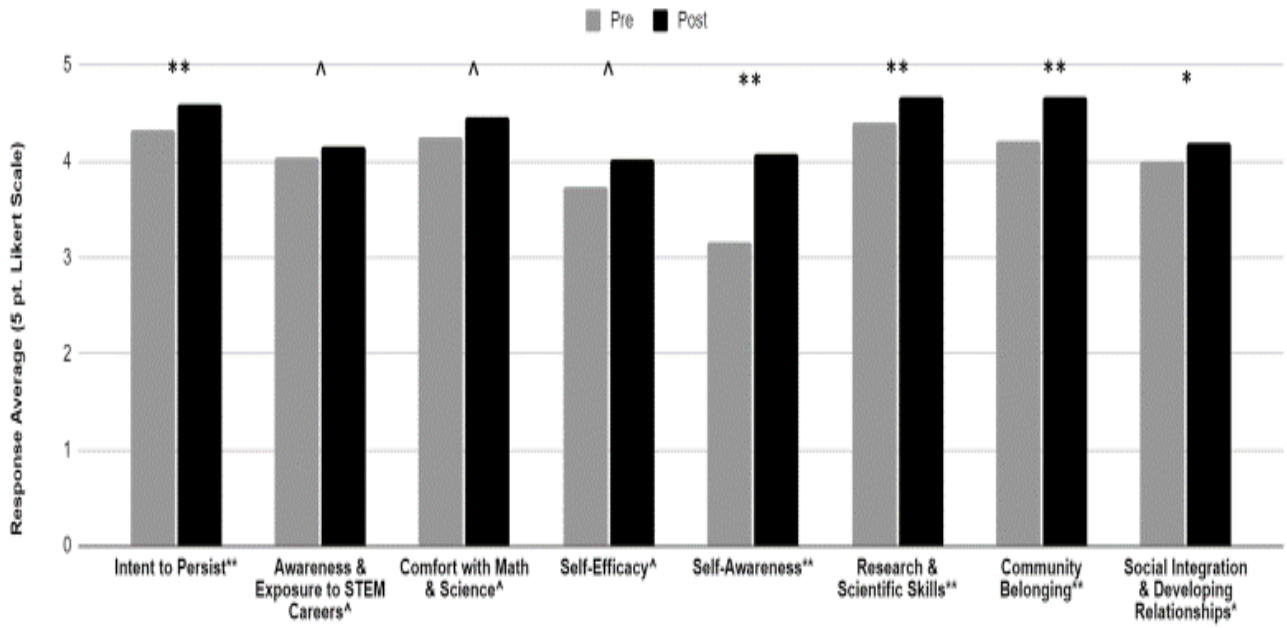
7. Self-Efficacy - Perceived self-efficacy refers to belief in one's agentive capabilities, that one can produce given levels of attainment; it includes both an affirmation of a capability level and the strength of that belief [33].

Each of constructs was measured using multiple representation items and response options were given using a 5-point Likert scale (1, strongly disagree to 5, strongly agree) to measure changes in their attitudes as a result of participating in the program. Student surveys were administered at the beginning and end of the program cohort. Item responses were averaged to identify a construct response average. Pair-sample t-tests were used to determine significant differences pre-to-post. In addition to participant surveys, focus group interviews with 3-5 students each were conducted. During the focus group interviews, students shared their thoughts and experiences about how the WiSTEM program impacted them. Focus group sessions were recorded, transcribed, and coded using a combination of open and sociologically constructed coding [34] or emergent themes.

RESULTS

Figure 1, below, indicates that students (n=110) showed significant growth in all measured areas. Overall, students responded positively to their experience in the WiSTEM program and found the program had a positive influence on their academic performance. Additionally, participants found the WiSTEM program significantly impacted their plans to persist in STEM, increased their self-awareness & self-efficacy (metacognition, identity), and increased resources for psychosocial support (community building, belonging).

Figure 1. Changes in student attitudes as a result of participating in the WiSTEM program, Summer 2007 - Summer 2022.



Response averages for students “Pre” WiSTEM and “Post” WiSTEM program; Item response options were 1=Strongly Disagree to 5=Strongly Agree. Levels of significance are indicated using: **p<0.001, *p<0.01, ^p<0.05.

These sentiments were further explained in the focus groups. In addition, participants’ community belonging and social interactions were increased through participating in the program; not surprisingly, this factor is an indicator of persistence. Furthermore, students in the program felt that they became more self-aware of being a Black woman in STEM. As they elaborated in the focus group interviews, community belonging, social interactions, and becoming more self-aware of being a Black woman in STEM were seen by participants as critical to their STEM success.

The quotes below demonstrate the impact of WiSTEM on participants’ self-awareness, self- efficacy, and psychosocial support:

<u>Self-Awareness & Self-Efficacy</u>

Participants discussed their self-awareness in terms of understanding how they occupy the space of STEM. More importantly, their participation in WiSTEM helped them embrace who they were as young Black women, grow as Black women socially and academically, build confidence, and gain a positive self-image in the STEM space. The comments ranged from imposter syndrome, learning how they studied, valuing their intellect, and their role as a Black woman in STEM.

So I'm at a point in my career now that [imposter syndrome] is damn near non-existent, like on the team that I'm on. It's 20 experts across different fields. They are all white men. I'm the only black person, I'm the only woman and they are all old. So I still look around and feel like I'm the smartest one in the room.... I belong at this table. I created my seat at this table.

….through WiSTEM, I sort of realized the necessity of women in STEM and kind of what that means…when you know your role, there's meaning [and purpose behind it].. [knowing that], it empowered me and it built my confidence….I felt more needed.

Psychosocial Support

Although community belonging and social interaction were not formally assessed for each cohort, it was mentioned throughout each focus group discussion as a factor that was beneficial to their academic growth but also influenced STEM student retention and career choice.

All of the girls here are so smart and hardworking. Being friends with them makes me want to push myself to be at the same level or at a higher level than they are.

The connections that I've made during this program have benefitted my academic growth because I am learning how to abandon bad habits and become a better student. I take more time studying and collaborating with peers to make sure I am learning correctly.

So I was never really alone... So it gave me a lot of confidence. I had, you know, built in, like, study partners, and it definitely improved my experience.... And I'm not an outgoing person...And I didn't feel like I had to find somewhere to like, fit in...

DISCUSSION

Many pre-College STEM programs are designed to boost the involvement of Black women in STEM, few investigate the impact of psychosocial support (community belonging, social interactions) on the intent to persist, decrease in math/science anxiety, self-efficacy, and self- awareness (realization of their contributions to the STEM field). Psychosocial support is important for Black women in STEM as numerous factors conspire against and undermine their ability to develop and maintain an interest in STEM [14]. On account many Black women in their STEM journey experience questioning of their skills and expertise in STEM-related topics; receive messages that

communicate, either explicitly or implicitly, that they do not belong in STEM; or experience having their presence and voice overlooked[15], social–psychological interventions can help to resolve these issues that undermine their comfort in STEM and their prospects for success.

Through credit-bearing math courses, enrichment series (personal and professional development), applied project modules, and study hall activities, WiSTEM participants were exposed to the value of collaboration, community, and vulnerability. The results of the WiSTEM program offer additional insight into the ways in which STEM belonging and identity for Black women can be developed through both formal and informal forms of support as well as how these supports positively affect their academic performance, matriculation in STEM disciplines, and STEM retention in the workplace. These results imply that psychosocial support and community work in tandem with motivation and are important to the intent to persist for Black women in STEM.

CONCLUSION

The WiSTEM program is a model of success that uses proven strategies to increase persistence in STEM among cohorts of Black women. In addition to using best practices, the program includes supports that address issues unique to this population of students. Surveys and focus group interviews of program participants indicate that they experience significant growth in their intent to persist in STEM, self-efficacy, self-awareness, research and scientific skills, community belonging, and social integration. Notably, 90% of WiSTEM participants graduate and at least 70% complete their degree in a STEM discipline. At 70%, the STEM retention rate for WiSTEM surpasses the College's rate of 45% and the national rate of 42% for students majoring in the physical sciences, computer science, and mathematics [35].

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