trends in higher education

MDPI

Article

Improving Retention and Success of African American Students in Computer Science: A Mixed-Method Case Study at an HBCU

Jung Won Hur [1], Cassandra Thomas [2], Li Huang [3] and Xiao Chang [2,*]

[1] Department of Educational Foundations, Leadership and Technology, Auburn University, Auburn, AL 36849-5216, USA; jwhur@auburn.edu
[2] Department of Computer Science, Tuskegee University, Tuskegee, AL 36088, USA
[3] Department of Psychology & Sociology, Tuskegee University, Tuskegee, AL 36088, USA
* Correspondence: xchang@tuskegee.edu

Abstract: This case study introduces the STARS (Supporting Talented African American Undergraduates for Retention and Success) project, designed to foster the retention and success of academically talented African American computer science students from low-income backgrounds at Historically Black Colleges and Universities (HBCUs) in the U.S. The STARS program employs a holistic approach, integrating four primary pillars of support: academic, social, career, and financial. Specific support provided includes near-peer mentoring, technical skill development seminars, undergraduate research, and high school outreach activities. To explore the program's effectiveness and areas of improvement, a mixed-method evaluation study was conducted, collecting data through surveys, observations, individual interviews, and focus group interviews. The findings revealed that the STARS program contributed to high levels of retention among its scholars, and the mentoring program provided valuable networking opportunities. The study suggests that the program's comprehensive approach, tailored to scholars' needs, and combined with a culturally affirming learning environment, facilitates the retention and success of talented African American students in computer science.

Keywords: black or African American; STEM; retention; computer science; HBCU; S-STEM; mentoring; sense of belonging

check for updates

Citation: Hur, J.W.; Thomas, C.; Huang, L.; Chang, X. Improving Retention and Success of African American Students in Computer Science: A Mixed-Method Case Study at an HBCU. *Trends High. Educ.* **2024**, 3, 912–927. https://doi.org/10.3390/higheredu3040053

Academic Editors: Carla C. Johnson and Janet B. Walton

Received: 29 August 2024
Revised: 27 October 2024
Accepted: 29 October 2024
Published: 3 November 2024

1. Introduction

The number of students pursuing four-year degrees in computer and information sciences in the U.S. has experienced a notable surge, rising by 34 percent from 2017 to 2022 [1]. However, beneath this overall growth lies a struggle to obtain a computer science (CS) degree, among females, individuals from low-income backgrounds, and traditionally underrepresented racial/ethnic minorities [2]. As of 2018, women earned 19% of computer science bachelor's degrees and 25% of doctoral degrees in the field [3]. Despite women making up 58% of overall college degree earners, their representation in CS remains notably low compared to other disciplines [3]. Black or African American students (African American hereafter) are especially underrepresented in CS [4]. While African Americans comprise 11% of all employed adults in the U.S., they make up only 7% of workers in computer occupations [3]. Additionally, a national survey of CS majors reveals a troubling trend; women and racial/ethnic minority students are more likely to leave the CS major compared to their male and white counterparts [5].

In the broader context of Science, Technology, Engineering, and Mathematics (STEM) fields, a study by Riegle-Crumb, King, and Irizarry [6] reveals that the likelihood of an African American student switching majors is approximately 19 percentage points higher than that of a white student. Additionally, studies indicate that access to STEM opportunities is restricted for students attending high-poverty secondary schools, where the lack of resources hinders their chances of pursuing STEM careers [7,8]. Research also revealed that students in low-income schools received fewer hands-on experiences in science classes and had decreased access to CS classes and resources [9]. Thus, while STEM careers can offer a pathway for low-income students to escape poverty, these students often encounter difficulties in pursuing a STEM degree [10].

To attract and retain academically talented minority and underrepresented CS students from low-income backgrounds, we have established the STARS (Supporting Talented African American undergraduates for Retention and Success) project. STARS scholars receive financial support of up to $10,000 annually for four years, accompanied by academic, social, and career support. This initiative has been made possible through funding from the NSF's S-STEM grant, and we have completed the first two years of our six-year project.

The purpose of this study is to examine the effectiveness of the STARS program's intervention activities during its first two years of implementation and identify areas of improvement. By examining the program's multi-faceted strategies and their impact, this research aims to contribute to the growing body of literature on STEM education, with a specific focus on supporting the retention and academic success of African American students in computer science.

2. Literature Review

2.1. Minority Students' Attrition in STEM

Despite the importance of educating enough STEM experts to drive technological advancements, the U.S. has grappled with retaining talented STEM students, particularly those from minority backgrounds and female students [11]. Nearly half of bachelor's degree students depart from STEM majors, either switching to non-STEM fields or leaving postsecondary education altogether [12]. This phenomenon has been labeled the "leaky STEM pipeline", where the initial pool of potential STEM workers appears substantial at the elementary and middle school levels. However, many students lose interest in subsequent grades or stages, shifting their focus to other, non-STEM subjects. Consequently, the number of students interested in STEM diminishes at all stages of education, resulting in a leaky supply pipeline that leads to fewer qualified STEM workers [13].

Research has identified multiple factors contributing to the leaky STEM pipeline issue, particularly the attrition of minority students in STEM. According to Ramsay-Jordan [9], African American students often attend underfunded schools that lack comprehensive STEM curricula, laboratory facilities, and experienced teachers. This disparity in educational opportunities hinders them from developing an interest in STEM and from acquiring the foundational skills and knowledge required for success in these fields [7].

Stereotype threat is also recognized as an important factor negatively affecting minority students' pursuit of a STEM degree. Stereotype threat is a psychological phenomenon where individuals feel at risk of confirming a negative stereotype associated with their group [14]. This awareness can lead to increased anxiety and stress during tests and presentations, preventing minority students from performing at their best [15]. Stereotype threat can have negative long-term effects on minority students' academic and career trajectories. McGee [16] found that despite academic success, high-achieving African American and Latino/a students experienced significant psychological strain as they felt compelled to conform to norms typically associated with white culture, leading to a loss of their cultural identity or leaving the STEM profession. Moreover, research has shown that stereotype threat can contribute to higher dropout rates among minority students in STEM fields. Beasley and Fischer [15] revealed that African American STEM majors exhibited the highest group-based performance anxiety, and those who expressed higher levels of anxiety had significantly higher odds of leaving STEM majors.

The underrepresentation of minority faculty and professionals in STEM can also contribute to higher attrition rates among minority students [17]. The absence of relatable role models and mentors makes it challenging for minority students to envision themselves as successful STEM professionals, potentially leading to feelings of isolation and increasing the likelihood of leaving STEM fields before completing their degrees [18,19].

2.2. Retention Strategies to Support Minority Students in STEM

To retain and support talented minority students in STEM fields, a growing body of research has explored various retention strategies. Mentoring has been highlighted as a vital approach to retaining minority students in STEM [20,21]. Effective mentoring programs provide academic guidance, professional development opportunities, and psychosocial support. A study by Wilson et al. [22] found that students who participated in mentoring programs were more likely to complete their degrees, prepare for graduate study, or enter the STEM workforce. Similarly, a study by Zaniewski and Reinholz [23] indicated that students who participated in mentoring programs reported that interactions with other students, faculty, and scientists boosted their confidence in studying STEM.

Peer or near-peer mentoring is also recognized as a way to boost minority students' STEM identity, sense of belonging, and self-efficacy, thereby increasing retention rates [23,24]. Peer mentoring is particularly useful not only for mentees to overcome difficulties but also for mentors, who appreciate opportunities to give back to their personal ethnic- and gender-specific communities. Providing near-peer mentoring helps mentors boost their sense of belonging and self-efficacy [24]. A study by Taylor et al. [25] examined how four African American undergraduate engineering students experienced and approached near-peer mentoring in a youth engineering camp and discovered the personal, academic, and professional benefits of being a mentor for high school minority students.

Engaging students in research experiences during their undergraduate studies positively influences their retention in STEM fields [20]. The aim of undergraduate research is "to involve students with actively contested questions, empirical observation, cutting-edge technologies, and the sense of excitement that comes from working to answer important questions" [21] (p. 10). The benefits of undergraduate research have been recognized, including providing mentoring opportunities, increasing retention and science identity, and expanding science conceptual understanding [26,27].

Notably, early access to undergraduate research has been found to be a crucial factor in retaining minority students in STEM fields. A study by Clancy-Wiik et al. [28] revealed that early access to undergraduate research was the most important factor positively impacting first-year underrepresented minority students' decisions to continue pursuing their STEM studies. Similarly, Bowman and Holmes [29] found that underrepresented minority students participating in first-year undergraduate research experiences have higher GPAs in their fourth year and are more satisfied with their postsecondary experience compared to their peers who did not participate in such programs.

Providing professional development workshops focused on topics such as time management, study skills, and career planning can equip minority students with the necessary skills and resources to navigate the challenges of STEM programs [30]. Tsui [31] stressed the significance of providing career counseling and guidance to African American students, noting their lack of personal connections with scientists. She also advocated for curriculum and instructional reforms, promoting more real-world problem-solving, technology integration, active learning, and collaborative group work. Providing academic counseling and research seminars can further assist minority students in comprehending the expectations and prerequisites of STEM programs, while also introducing them to potential research avenues [31].

A systematic review by Pearson et al. [32] identified ten essential components of successful retention intervention programs, including targeted academic interventions such as enrichment classes and small group problem-solving sessions, and community services like volunteer work and mentoring K-12 students. Additionally, summer bridge programs, which include mentoring, study skills workshops, research opportunities, and team-building exercises, were found to be particularly effective in helping minority students acclimate to their academic environments, boosting their confidence, and fostering connections with peers and faculty [33]. While strategies to support STEM retention have been widely studied, scholars have found that no single element can guarantee improved student retention [32]. Rather, an integrated approach employing a combination of effective strategies is crucial to providing the necessary support to increase retention, particularly among minority students [31].

3. STARS Program Development

To guide minority students' retention in CS, we developed a conceptual model based on Tinto's theory of student dropout [34]. The theory emphasizes the critical interplay between individual commitment and institutional commitment in influencing student retention. Students enter higher education with diverse background characteristics (e.g., family background and previous schooling experiences) and varying levels of commitment to both completing their degree (i.e., goal commitment) and to the institution they are attending (i.e., institutional commitment). The theory posits that students are more likely to persist and complete their degrees when there is a strong alignment between their personal goals and the support they receive from the institution. This alignment fosters a sense of belonging and integration into the academic and social life of the institution.

When students feel academically and socially integrated, their commitment to both their personal educational goals and the institution is strengthened, significantly reducing the likelihood of dropout. The theory emphasizes the importance of institutional commitment to fostering an environment that promotes academic and social integration, thereby strengthening students' commitment and increasing their likelihood of persistence. Institutions need to provide appropriate resources, support systems, and opportunities for students to become integrated members of the campus community.

The STARS model integrates four primary types of support: academic support, social support, career support, and financial support, all supplemented by continuous check-ups to ensure ongoing student engagement and success (see Figure 1). Academic support in the STARS program includes academic advising, early alert systems, and individual mentoring. Social support involves faculty and near-peer mentoring and social events. Career support encompasses career counseling, professional development, and summer internship opportunities. Undergraduate research opportunities and weekly mentoring sessions are also offered throughout the semester to help scholars improve their technical skills, strengthen their resumes, and build connections with fellow STARS scholars. These activities are designed to comprehensively address academic, career, and social support needs. To remove financial barriers, the project provides STARS scholars with up to a $10,000 scholarship per year. We also provide them with an opportunity to become teaching or research assistants, providing additional monetary support.

Figure 1. STARS program conceptual framework.

4. STARS Program Implementation (The Case)

4.1. Background: About the University

Our university, a Historically Black College and University (HBCU), is situated in the southeastern region of the United States. In 2020, a total of 2529 undergraduates were enrolled, with the majority of the student body being African American students. Financially, 66% of our students receive aid in the form of Pell Grants from the U.S. Federal Government, with an average award amount of $4250. About 52% of our students come from low-income families, defined as those with incomes below twice the federal poverty level for their family size in 2020. Additionally, 62% of our students take out student loans, incurring an average loan debt of $5500 per year. To meet their financial needs, most students work on or off campus during the academic year.

4.2. STARS Scholar Participant Recruitment

Our project was funded in October 2022, and we began recruiting the first cohort of participants immediately. To be eligible, scholars must earn a minimum of a 3.0 high school GPA, come from a low-income family, and demonstrate financial needs. Applicants were also required to submit a resume, up to two reference letters, and SAT or ACT scores. Through document reviews and interviews, we selected six scholars for the first cohort in the 2022–2023 academic year and five scholars for the second cohort in the 2023–2024 academic year.

4.3. STARS Intervention Activities

Over the past two years, we have implemented a comprehensive support system for our STARS scholars, encompassing a wide range of academic, social, and career development components. Scholars benefited from academic and career mentoring, with faculty and peer mentors leading sessions on time management, internship search strategies, job interview techniques, and AI research. Next, we provided ongoing academic support, including guidance on curriculum sequencing and course recommendations each semester to help scholars stay on track to graduate on time. Personalized academic advising, with early alert support through transcript reviews and individual meetings, was also offered to assist scholars in successfully completing their coursework. Additionally, we facilitated technical skills development through professional development seminars. For instance, we offered Python programming workshops for scholars interested in learning the language, which is not currently offered by the department. Additionally, to help freshman scholars with limited programming experience, we offered hands-on coding activities using Sphero Bolt, developed by Sphero, Inc., based in Boulder, CO, USA.

We encouraged scholars to pursue undergraduate research opportunities to explore potential career paths, develop new skills, and expand their personal research networks. As a result, scholars have engaged in various faculty-led research projects, including deep learning, quantum computing, virtual reality, and AI integration in agriculture. We also encouraged all participants to attend the annual NSF S-STEM Scholar Meeting, providing them with the opportunity to present their research and network with other scholars, further enhancing their career prospects. Lastly, STARS scholars were encouraged to participate in high school outreach activities. They have served as guest speakers at a high school CS summer camp and taught high school students how to program Sphero Bolt at a university-led outreach event.

5. Methods

By providing academic, financial, social, and career support, the STARS program aims to accomplish several primary goals: (a) help scholars maintain a GPA above 3.0, (b) ensure at least a 75% first-year retention rate, (c) support scholars in achieving a four-year graduation rate of over 60%, and (d) improve the overall quality of instruction at the university. A formative evaluation [35] was conducted to assess the contribution of

STARS intervention activities toward these goals and to recommend improvements for future activities.

This study utilized two evaluation approaches: objective-oriented and participant-oriented [36]. The objective-oriented approach evaluated whether specific goals and criteria are being met. Given that the program has only been in place for two years, graduation data have not yet been collected. Therefore, this study focused on exploring scholars' GPA and retention rates. In contrast, the participant-oriented approach examined the program from the perspectives of its participants, assessing whether it meets their needs. In this study, we aimed to gather insights into scholars' views on the intervention activities provided, as well as any challenges they faced and their suggestions for program improvement.

To incorporate these approaches, we conducted a mixed-method evaluation study, which used both quantitative and qualitative data collection and analysis techniques to answer evaluation questions [37]. According to Greene, Benjamin, and Goodyear [38], mixing methods in evaluation has several benefits including "increased validity, more comprehensiveness of findings, more insightful understanding and greater value conciseness and diversity" (p. 41). We employed a mixed-method approach not only to validate findings by directly comparing and contrasting quantitative and qualitative results but also to develop a more complete understanding of scholars' experiences [38]. We used the convergent parallel design in which qualitative and quantitative data were collected simultaneously but analyzed separately [39]. According to Fitzpatrick, Sanders, and Worthen [36], evaluation questions provide the essential framework and direction for a study. Therefore, this study was guided by the following evaluation questions:

1. To what extent do the STARS activities contribute to the academic success and retention of STARS scholars?
2. What are the participants' perspectives on the mentoring and professional development seminars (i.e., Python programming and block coding)?
3. What challenges have STARS scholars encountered while participating in STARS activities?
4. What suggestions do STARS scholars have for future activities that could enhance their academic engagement?

5.1. Participants

The participants were all the 11 STARS scholars in the first two cohorts. Six of them were from the first cohort of 2022–2023, while five were from the second cohort of 2023–2024. As of June 2024, the six first-cohort scholars have completed their sophomore year. The five second-cohort scholars have finished their freshman year. Two of the first-cohort scholars were female, and four of the first-cohort scholars were male. All participants were African American and selected after the verification of the scholars' qualifications, such as a high school GPA of over 3.0, a demonstrated financial need, strong recommendation letters, and an exhibited academic potential.

5.2. Data Collection

Prior to data collection, the study received approval from the authors' institutional review board. All participants were given detailed information about the study and voluntarily signed informed consent forms. Following participant consent, both quantitative and qualitative data were collected for two years to examine the program's impact and identify areas of improvement. Table 1 below indicates specific data collected and analysis methods to answer each of the evaluation questions.

Table 1. Data collection and data analysis techniques.

Evaluation Question	Data Collection	Data Analysis
1. Impact on academic success and retention	Transcripts; Enrollment records; Happiness survey	Descriptive statistics; Comparing enrollment status with non-STARS scholars
2. Impact on mentoring program and professional development seminars	Pre- and post-surveys; Individual interviews; Focus group interviews; Observations	Wilcoxon signed-rank test; Descriptive statistics; Thematic analysis; Focused coding
3. Challenges encountered	Observations; Individual interviews	Thematic analysis; Focused coding
4. Suggestions for future activities	Focus group interviews; Individual interviews	Thematic analysis; Focused coding

To answer question 1, we collected all scholars' transcript records each semester. These data were used not only to assess whether scholars maintained a GPA of 3.0 or above but also to identify students at risk of dropping out. Additionally, we collected retention data for STARS cohort and non-cohort groups (i.e., students in the CS department who started the program with STARS scholars) from 2022 to 2023 and 2023 to 2024. While three scholars completed their junior year, two of them transferred to the university in 2022, meaning they joined the cohort of 2022–2023. Therefore, we only compared these two academic years. Finally, to gauge the possibility of retaining the program based on the overall happiness of scholars, we included a survey question: "How happy are you with your choice to pursue a degree in computer science at this university?" Scholars rated their perceived happiness on a 5-point Likert scale, from 1: Not at all happy, 2: Slightly happy, 3: Somewhat happy, 4: Quite happy to 5: Extremely happy.

To answer question 2, pre- and post-surveys, interviews, and focus group interviews were conducted. Before the mentoring program started, we conducted a pre-survey measuring scholars' sense of belonging, perceived institutional support, and intention to retain in the program. The survey items were adapted from previous studies [2,40] and used a five-point Likert scale (1: strongly disagree to 5: strongly agree). After the mentoring program, a post-survey including the same questions, along with additional questions exploring scholars' overall evaluation of the mentoring program, was conducted. These items also used a five-point Likert scale (1: strongly disagree to 5: strongly agree). At the end of the mentoring program, we conducted a focus group interview to explore scholars' overall perceptions of the mentoring program and suggestions for future activities.

To measure the impact of the professional development seminars, we observed meetings, noting the number of participants and the nature of seminars. After the seminars, a brief survey exploring participants' overall perceptions of the effectiveness of professional development was given. We also interviewed both the instructors and active participants of seminars to explore their experiences. To answer question 3, we collected seminar observation notes and conducted interviews with participants. During individual interviews, we asked about their perceptions of the activities provided and challenges encountered. Finally, during the focus group interviews and individual interviews, we asked scholars about ideas for future activities to answer question 4.

5.3. Data Analysis

For question 1, we compared the retention rates of STARS scholars and non-STARS scholars. Additionally, we reported the cumulative GPA of STARS scholars for the spring 2024 semester and calculated the mean happiness score. For question 2, we conducted descriptive statistics to summarize the post-survey data. To evaluate the effectiveness of the mentoring program, we first conducted the Shapiro–Wilk test to assess the normality of the data distribution. As the results indicated a non-normal distribution ($p < 0.05$), we applied the Wilcoxon signed-rank test to analyze the differences. The quantitative data were analyzed using SPSS 29.0. The Shapiro–Wilk test and Wilcoxon signed-rank test were performed on the variables that we determined, including survey items on a sense of belonging, perceived institutional support, and the intention to retain. Qualitative data were analyzed using thematic analysis [41]. After familiarizing ourselves with the dataset, we applied open codes including descriptive, structural, and in vivo codes as appropriate [42]. Focused coding followed, selecting codes directly related to the evaluation questions. Thematic analysis and focused coding were also employed to answer questions 3 and 4, similar to the qualitative data analysis for question 2. Data triangulation was performed by comparing findings from multiple scholars' perspectives and synthesizing insights from different data sources, such as interviews, observations, and focus group interviews.

6. Findings

6.1. Retention and Academic Success

The comparison of the retention rate of the STARS cohort and non-cohort demonstrated a higher level of CS retention for STARS scholars, indicating the effectiveness of the STARS program in retaining African American students from low-income families (see Table 2). In the fall of 2022, a total of 32 students were admitted to the CS department. As of June 2024, 14 students were retained in the program (44% retention rate). On the other hand, 100% of the first STARS cohort remained in the CS department. In fall 2023, a total number of 32 students were admitted to the CS department, and 21 of them remained in the program as of June 2024 (66% retention rate). STARS scholars' retention rate is higher at 100%.

Table 2. Retention rate comparison between STARS scholars and non-STARS.

Cohort	STARS Scholars	Non-STARS
2022–2023 Cohort	100% (6/out of 6)	44% (14/out of 32)
2023–2024 Cohort	100% (5/out of 5)	66% (21/out of 32)

Additionally, we explored scholars' overall GPAs to ensure that the program supports the academic success of scholars. According to the GPA records of spring 2024, 9 out of 11 scholars demonstrated a GPA over 3.0, ranging from 3.04 to 4.00. While two second-cohort scholars fell below 3.0, they remained committed to pursuing their CS degrees. The analysis of the happiness survey revealed a mean score of 3.90 (SD = 0.876) on a 5-point scale. This rating suggests that scholars feel quite happy about studying at the institution. This positive sentiment suggests a strong likelihood of persistence and retention within the CS department for all scholars.

6.2. Impact of Mentoring

The impact of the mentoring program that facilitates academic and social support were examined by comparing the pre- and post-surveys, including the survey items on a sense of belonging, institutional support, and the intention to retain. The Wilcoxon signed-rank test revealed that there were no statistically significant changes in students' sense of belonging, perception of institutional support, or intention to retain in the program between the pre- and post-surveys (see Table 3). However, qualitative data analysis revealed that scholars appreciated the opportunity to connect with peers through mentoring meetings. During a focus group interview, one student remarked, "Meeting other scholars and networking was beneficial". This sentiment was echoed by another participant who stated, "The mentoring was a good opportunity to connect with other scholars".

Table 3. Pre- and post-survey comparison results.

Survey Item Category	Survey Item (Variable)	Pre-Median	Post-Median	Z (*p* Value)
Sense of Belonging	• I have a lot in common with the other students in my CS classes.	4.00	4.00	−0.707 (0.480)
	• People like me belong in the CS community.	4.00	5.00	−1.34 (0.180)
	• I feel a part of the computer science department.	5.00	5.00	−0.577 (0.564)
	• I have developed quality of relationships with other students at my university.	5.00	5.00	−1.414 (0.157)
	• I have developed quality of relationships with faculty members at my university.	4.00	4.00	−1.00 (0.317)
Institutional Support	• My university provides me with the support I need to help me succeed academically.	4.00	4.00	−0.577 (0.564)
	• My university provides me with the support I need to thrive socially.	4.00	5.00	−1.414 (0.157)
Intention to Retain	• I plan to continue to work towards my degree.	5.00	5.00	−1.00 (0.317)
	• It is likely that I will earn a computer science degree.	5.00	5.00	−1.00 (0.317)
	• If I had a good alternative, I would drop out of this program or change the program.	2.00	2.00	−0.447 (0.655)
	• I have already thought quite a few times about dropping out of my program.	2.00	2.00	−1.035 (0.301)

The analysis of the post-survey, measuring scholars' overall perceptions of the mentoring program, revealed a high level of scholars' satisfaction with the mentoring activities (see Table 4). Scholars indicated that the meetings not only helped them connect with other scholars (M = 4.50; SD = 0.548) but they also learned useful lessons such as time management (M = 4.18; SD = 0.603). They also indicated that the meetings were beneficial for them (M = 4.45; SD = 0.522). Findings from the analysis of the focus group interviews also confirmed the quantitative findings. During the focus group interviews, one scholar stated, "These mentoring meetings have been useful as they have offered perspective shifts. They have given us insight into the types of opportunities and learning experiences offered in the field of computer science".

Table 4. Scholars' perceptions of the impact of the mentoring program.

Survey Item (Variable)	Mean	SD
• The mentoring meetings helped me think about my short-term and long-term goals.	4.27	0.905
• The internship session provided valuable insights into future internship opportunities.	3.73	1.104
• The time management workshop provided me with practical strategies to manage my time.	4.18	0.603
• Meeting with other CS major students motivated me to succeed in the CS program.	4.17	0.753
• The mentoring meetings helped me connect with other S-STEM scholars.	4.50	0.548
• The content of the meetings was relevant and valuable to my academic and career goals.	4.27	0.467
• Overall, the mentoring meetings have been beneficial to me.	4.45	0.522

6.3. Impact of Technical Skill Development Seminars

The participation records of the two seminars, Python 3 and block coding, showed that 12 students from various programs attended the first Python seminar, while 13 CS freshmen attended the first block coding meeting. Although the initial meetings were well attended, the participation gradually decreased as the semester progressed. While attendance decreased, those students who participated in the program demonstrated very high satisfaction with the seminars. According to the evaluation survey of the first Python seminar, participants indicated that the session increased their confidence in Python programming and found it a valuable learning experience (see Figure 2). The participants of the first block coding seminar also indicated that the seminar boosted their confidence in block programming, and they would recommend it to others interested in learning block programming (see Figure 3). The graphs given in Figure 2; Figure 3 were created with Microsoft Excel 2016. The analysis of the interview data confirmed the participants' satisfaction with the seminars. One of the STARS scholars who continued to participate in the Python seminar indicated that the lessons exposed him to another programming language not taught in regular classes, in a relaxed and conducive environment. The absence of test-related stressors, coupled with the opportunity to freely seek guidance from instructors, helped him enjoy the experience.

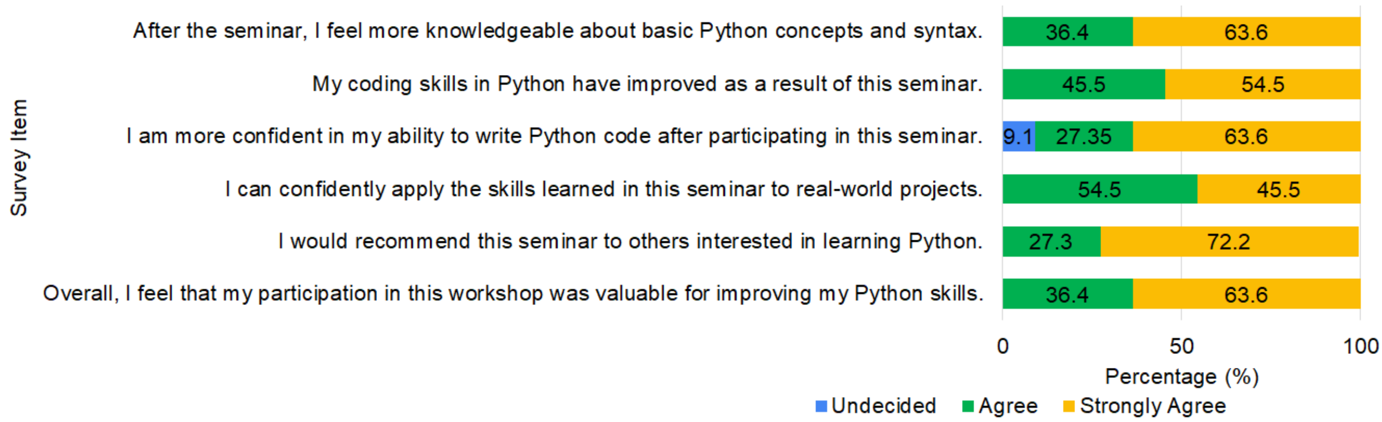

Figure 2. Python seminar post-survey results.

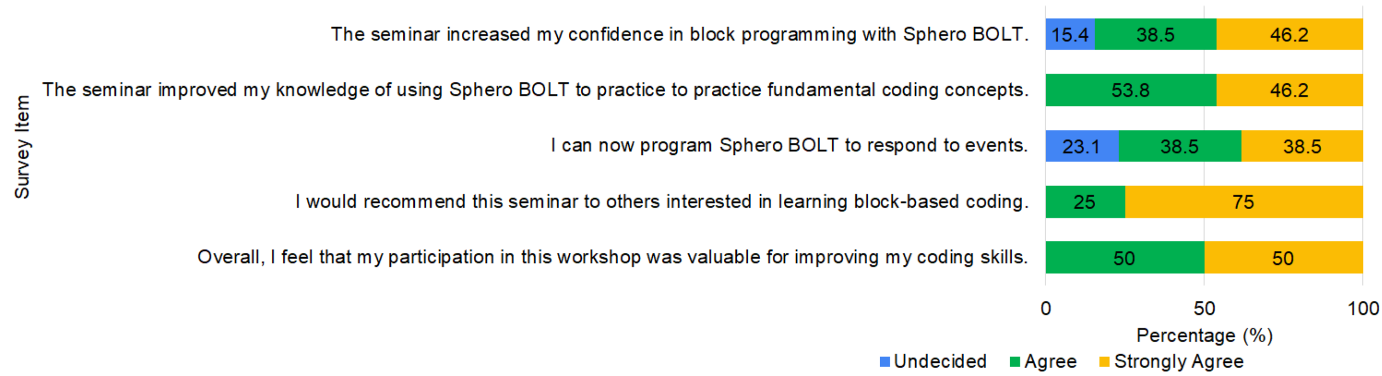

Figure 3. Begin to code seminar post-survey results.

The block programming lessons were taught by three scholars from the first cohort. The analysis of the interview data revealed that the experience helped them develop soft skills such as communication and time management. One scholar talked about how the experiences helped improve his communication skills, expressing, "It helped me improve my communication skills like finding common ground between me and the students to make them feel more comfortable". Another scholar indicated an improvement in time management skills. She said, "the experience helped me a lot with time management because it was a week-to-week thing in which we prepared the lessons for the students. It definitely helped me get everything done on time".

6.4. Challenges

According to the analysis of the observation notes and interview data, finding a time when every scholar could join the mentoring meetings was a challenge. Scholars had different class schedules, and those participating in research groups or other student organizations had additional obligations, which created time conflicts with STARS scholar meetings. As a result, some scholars joined the meetings late or had to leave early, potentially diminishing the overall impact of the meetings. Finding a suitable time for technical development seminar participants was also challenging, as they had varied class schedules, labs, and school events. One scholar who led the block coding lessons explained a possible reason for the decreased participation as the semester progressed. He said, "Part of it has to do with school events, because I know like homecoming was going on, and it was like their first homecoming since they're freshmen, so I know they wanted to participate in that".

Meeting the needs of each scholar, who had different technical levels and experiences, was another challenge. While the Python seminar was intended to assist the first cohort of STARS scholars as well as other students lacking Python programming experience, half of the STARS scholars were already familiar with it, making the lessons less beneficial for them. The analysis of observation notes indicated that freshmen found the internship mentoring session useful, whereas juniors found it less effective due to their prior experience. For the block programming seminar, scholars who taught the lessons revealed that Sphero Bolt lessons were too easy for participants as they were designed for K-12 students, causing a drop in attendance. One scholar explained, "I feel like Sphero Bolt lessons are designed for middle schoolers or maybe high school students, not college students. Once we planned the activities, students typically got through them in about 15 to 20 min. We had to use a lot of improvisation to get them to do more than what was required. It was hard. We thought it would be fun for them to work with robots, but they didn't necessarily think so. I feel like that's why attendance at the seminars dropped". Finally, while scholars appreciated the variety of activities provided, they sometimes felt overwhelmed by the number of meetings. Additionally, providing various activities throughout the semester demanded a considerable amount of faculty time, requiring them to work nights and weekends.

6.5. Suggestions for the Program

Despite the challenges encountered, scholars acknowledged the benefits of technical development seminars and mentoring sessions, both for themselves and future STARS scholars. For future technical skill development seminars, they suggested sending out more frequent reminders, providing incentives for participation, and incorporating additional hands-on activities to increase participation and retention. They also recommended allowing collaborative work among students and offering more class demonstrations to make the lesson more engaging and beneficial for participants. Regarding the mentoring sessions, scholars proposed meeting in smaller groups or with a limited number of individuals at a time, as well as including more hands-on activities to foster engagement. Some scholars suggested exploring Zoom/hybrid meetings instead of face-to-face meetings, incorporating coding projects to build resumes, and organizing field trips to technology companies for career explorations.

7. Discussion

The study explored the impact of the STARS program and examined the areas of improvement. The findings demonstrated a positive impact of the program, with scholars exhibiting a retention rate of 100%. Additionally, the results highlighted the benefits of the mentoring program in providing valuable networking opportunities and emphasized the importance of peer-led professional development seminars. These seminars contributed to the development of essential soft skills, such as communication and time management. Although the first two years of the program were generally successful, several challenges emerged, including scheduling conflicts, varying individual needs, and decreased attendance in technical skill development seminars. Scholars appreciated the overall programs and suggested enhancements, such as incorporating hands-on activities into sessions and forming smaller, more flexible mentoring groups to better accommodate diverse student needs.

Other studies focusing on cohort-based programs supporting low-income and underrepresented students' retention in STEM, such as the LiFT Scholars Program [43] and the I-PASS program [2], have reported similar results. These programs include interventions such as peer mentoring, undergraduate research, summer bridge programs, and financial support, which have positively influenced retention rates and students' sense of belonging. However, these studies were conducted at large, public, urban, 4-year or 2-year universities, while our study was conducted at a small, private, rural, 4-year HBCU. Despite the significant contributions that HBCUs have made in training future STEM experts [44], efforts made by HBCUs to retain STEM students are not well documented. Our study contributes to the existing literature by highlighting an HBCU's efforts to retain minority students from low-income families.

One possible reason for the high level of retention and satisfaction among STARS scholars demonstrated in this study is the institutional emphasis on creating a supportive learning environment. Studies have indicated that studying in an HBCU context boosts racial identity and academic motivation by providing opportunities to engage with other African Americans who are attaining success [45]. At predominantly white institutions (PWIs), African American students often face stereotype threats [46], which can undermine their academic performance and persistence [16]. However, by providing a culturally affirming space, the STARS program mitigates this threat and empowers scholars to embrace their identities without the fear of judgment or marginalization.

While the post-survey data examining scholars' general perceptions of the mentoring program revealed positive impacts, the pre- and post-survey comparison using the Wilcoxon signed-rank test showed no statistically significant differences. This lack of significant change may be attributed to scholars already having positive perceptions and strong intentions to persist in the program. Indeed, students' median scores for a sense of belonging and institutional support were consistently high (four or five on a five-point Likert scale), while intentions to drop the program remained consistently low (median of two). The high scores in both pre- and post-surveys suggest that the program is maintaining, rather than significantly enhancing, an already positive student experience. These results imply that the university effectively fulfills its mission to support African American students by enabling them to engage with their culture, facilitating relationships with peers and faculty, and providing support that promotes their cultural identity. This nurturing environment appears to foster a strong sense of belonging and academic resilience, which are critical factors for the retention of minority students in STEM fields [43].

Initial interest in Python and block coding PD seminars should be noted. For the first Python seminar, a total of 29 students from seven different programs signed up, and 21 students signed up for the block programming seminar. While not everyone who signed up attended the seminars, these data showed students' keen interest in such opportunities. This implies the importance of providing various technical skill development seminars for students who are looking to not only learn new technical skills and knowledge but also connect with fellow students, which can foster a sense of belonging and community [20,32].

When designing technical skill seminars, the timing of these seminars should be carefully considered. Due to conflicts with other school events and classes, attendance decreased as the semester progressed. Perhaps more intensive sessions with fewer meetings could help students attend such events without time conflicts. Offering technical skill development opportunities during breaks may increase accessibility and participation. Research has shown that programs created for minority students are beneficial for all students on campus [31]. Therefore, institutions should continue to offer technical skill development seminars that could benefit the entire student body, promoting an inclusive and supportive environment for STEM students, particularly those from underrepresented groups.

It is crucial to acknowledge that scholars have diverse needs stemming from their varied backgrounds. While some requested support in enhancing technical skills, others sought guidance in navigating social dynamics. No single intervention can effectively address the unique requirements of every individual scholar [31]. Instead, it is imperative to continuously examine and assess the evolving needs of these students, as their priorities and challenges may shift as they progress academically.

Even in the context of technical skill session design, we have learned that students bring with them various levels of skills, knowledge, and interests. Adapting and tailoring lessons based on these diverse needs are essential to develop sessions that are useful and impactful for a broad spectrum of students. By embracing a flexible and responsive approach, STEM programs can foster a sense of inclusivity and belonging, thereby increasing the retention of minority students.

- Limitations of Study and Future Studies

While we collected both quantitative and qualitative data to enhance the validity and credibility of our findings [38], it is important to acknowledge the limitations of this study. Since the STARS program was established only two years ago, our retention data span just two years. This short timeframe limits our ability to assess long-term effects such as graduation rates, employment, or workforce outcomes. We plan to extend the data collection period to include multiple cohorts over several years to provide a more comprehensive analysis of the program's long-term impact.

Another limitation is the potential for social desirability bias. Scholars may feel pressure to provide socially acceptable answers due to the misconception that their scholarship might be affected by their responses. To mitigate this issue, we clearly explained that the purpose of the study was to assess the quality of the program rather than to evaluate the scholars' performance. We also used questioning techniques suggested to reduce social desirability bias, such as using indirect questions, requesting examples, and probing for more information [47].

While the STARS program provided a variety of activities, the findings of this study only focused on mentoring and technical skill development seminars. We selected these two activities because all scholars participated in the mentoring program, whereas only a specific group of students participated in other activities. Due to this limitation, the study could not identify the distinct contributions of each activity. While we acknowledge the importance of an integrated approach that combines multiple effective strategies [31], understanding the unique impact of each intervention could help us better allocate resources and time. As we continue to improve the program, we plan to collect more data and examine the individual impacts of various intervention activities.

We originally aimed to recruit at least 50% female scholars, but we were not able to achieve this goal due to a lack of eligible participants in the department. We will continue to recruit more female participants. Once we collect more data from female participants, comparing female and male African American students' college experiences can provide valuable insights into offering differentiated support for male and female students. Research indicates that gender-specific challenges exist in STEM fields [48] and addressing these through tailored support mechanisms can improve retention and success rates for both female and male African American students.

8. Conclusions

In conclusion, this study highlights the effectiveness of the STARS program in enhancing retention and success for African American students from low-income backgrounds in STEM. The program's holistic approach—combining academic, social, career, and financial support—has successfully created a nurturing environment that empowers students to excel. The program has provided valuable networking opportunities and enhanced essential soft skills through mentorship and peer-led professional development. Additionally, the findings emphasize the importance of tailoring interventions to address diverse student needs and the necessity of ongoing evaluation to adapt to evolving circumstances. This research contributes to the growing body of literature on STEM education by underscoring the critical role of HBCUs in supporting minority students in these fields. Ultimately, we aspire for the STARS program to serve as a model for similar initiatives that promote diversity and inclusion in STEM education and careers.

Author Contributions: Conceptualization, J.W.H. and X.C.; methodology, J.W.H. and X.C.; validation, J.W.H. and L.H.; investigation, J.W.H. and X.C.; resources, J.W.H. and X.C.; data curation, J.W.H. and L.H.; writing—original draft preparation, J.W.H.; writing—review and editing, J.W.H. and X.C.; visualization, J.W.H. and X.C.; supervision, X.C.; project administration, C.T. and X.C.; funding acquisition, X.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Science Foundation (grant numbers 2221115 and 2306141).

Institutional Review Board Statement: The study was conducted in accordance with Tuskegee University and Auburn University, and approved by the Institutional Human Participant Research Committee of Tuskegee University (IRB Number 00001137, 30 June 2022) and Institutional Review Board of Auburn University (approval code23-052 EX 2303, 15 March 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data supporting reported results are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Anderson, N. College is Remade as Tech Majors Surge and Humanities Dwindle, Washington Post. Available online: https://www.washingtonpost.com/education/2023/05/19/college-majors-computer-science-humanities/ (accessed on 1 August 2024).
2. Mickelson, R.A.; Mikkelsen, I.; Dorodchi, M.; Cukic, B.; Horn, T. Fostering greater persistence among underserved computer science undergraduates: A descriptive study of the I-PASS Project. *J. Coll. Stud. Retent. Res. Theory Pract.* **2024**, *26*, 445–472. [CrossRef]
3. Pew Research Center. STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity. Available online: https://www.pewresearch.org/social-trends/2021/04/01/stem-jobs-see-uneven-progress-in-increasing-gender-racial-and-ethnic-diversity/ (accessed on 1 April 2021).
4. National Center for Science and Engineering Statistics (NCSES). Diversity and STEM: Women, Minorities, and Persons with Disabilities. In *Special Report NSF*; National Science Foundation: Alexandria, VA, USA, 2023. Available online: https://ncses.nsf.gov/wmpd (accessed on 30 January 2023).
5. Tamer, N.B.; Stout, J.G. Recruitment and Retention of Undergraduate Students in Computing: Patterns by Gender and Race/Ethnicity. 2016. Available online: https://cra.org/cerp/wp-content/uploads/sites/4/2017/05/CS_RecruitmentRetention.pdf (accessed on 24 July 2016).
6. Riegle-Crumb, C.; King, B.; Irizarry, Y. Does STEM stand out? Examining racial/ethnic gaps in persistence across postsecondary fields. *Educ. Res.* **2016**, *48*, 133–144. [CrossRef] [PubMed]
7. Bottia, M.C.; Mickelson, R.A.; Jamil, C.; Moniz, K.; Barry, L. Factors associated with college STEM participation of racially minoritized students: A synthesis of research. *Rev. Educ. Res.* **2021**, *91*, 614–648. [CrossRef]
8. Lundy-Wagner, V.C.; Veenstra, C.P.; Orr, M.K.; Ramirez, N.M.; Ohland, M.W.; Long, R.A. Gaining access or losing ground? Socioeconomically disadvantaged students in undergraduate engineering, 1994–2003. *J. High. Educ.* **2014**, *85*, 339–369. [CrossRef]
9. Ramsay-Jordan, N.N. Hidden figures: How pecuniary influences help shape STEM experiences for Black students in grades K-12. *J. Econ. Race Policy* **2020**, *3*, 180–194. [CrossRef]
10. Cline, E.; Bjorling, E.; Cilli-Turner, E.; Dinglasan-Panlilio, J.; Heller, J.; Kolodziej, E.; Camey Kuo, A.; Nahmani, M.; Sesko, A.; Wenderoth, M.P.; et al. Promoting academic success of economically disadvantaged, STEM-interested, first- and second-year undergraduate students via the ACCESS in STEM program at University of Washington Tacoma. In Proceedings of the 2023 American Society for Engineering Education Conference, Baltimore, MA, USA, 25–28 June 2023.
11. Witteveen, D.; Attewell, P. The STEM grading penalty: Challenging the "leaky pipeline" hypothesis. *Sci. Educ.* **2020**, *104*, 714–735. [CrossRef]
12. Chen, X. *STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001)*; National Center for Education Statistics, Institute of Education Sciences Department of Education: Washington, DC, USA, 2013.
13. Wu, J.; Uttal, D. Beyond the leaky pipeline: Developmental pathways that lead college students to join or return to STEM majors. *J. Res. STEM Educ.* **2020**, *6*, 64–90. [CrossRef]

14. Steele, C.M. A threat in the air: How stereotypes shape intellectual identity and performance. *Am. Psychol.* **1997**, *52*, 613–629. [CrossRef]
15. Beasley, M.A.; Fischer, M.J. Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math, and engineering majors. *Soc. Psychol. Educ.* **2012**, *15*, 427–448. [CrossRef]
16. McGee, E.O. Interrogating Structural Racism in STEM Higher Education. *Educ. Res.* **2020**, *49*, 633–644. [CrossRef]
17. Whittaker, J.A.; Montgomery, B.L.; Martinez Acosta, V.G. Retention of underrepresented minority faculty: Strategic initiatives for institutional value proposition based on perspectives from a range of academic institutions. *J. Undergrad. Neurosci. Educ.* **2015**, *13*, A136–A145. [PubMed]
18. Dortch, D.; Patel, C. Black undergraduate women and their sense of belonging in STEM at predominantly white institutions. *NASPA J. About Women High. Educ.* **2017**, *10*, 202–215. [CrossRef]
19. Kricorian, K.; Seu, M.; Lopez, D.; Ureta, E.; Equils, O. Factors influencing participation of underrepresented students in STEM fields: Matched mentors and mindsets. *Int. J. STEM Educ.* **2020**, *7*, 1–9. [CrossRef]
20. Estrada, M.; Hernandez, P.R.; Schultz, P.W. A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE Life Sci. Educ.* **2018**, *17*, ar9. [CrossRef] [PubMed]
21. Lisberg, A.; Woods, B. Mentorship, mindset, and learning strategies: An integrative approach to increasing underrepresented minority student retention in a STEM undergraduate program. *J. STEM Educ.* **2018**, *19*, 14–20. Available online: https://www.jstem.org/jstem/index.php/JSTEM/article/view/2280 (accessed on 14 August 2018).
22. Wilson, Z.S.; Holmes, L.; de Gravelles, K.; Sylvain, M.R.; Batiste, L.; Johnson, M.; McGuire, S.Y.; Pang, S.S.; Warner, I.M. Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate stem disciplines. *J. Sci. Educ. Technol.* **2012**, *21*, 148–156. [CrossRef]
23. Zaniewski, A.M.; Reinholz, D. Increasing STEM success: A near-peer mentoring program in the physical sciences. *Int. J. STEM Educ.* **2016**, *3*, 1–12. [CrossRef]
24. Trujillo, G.; Aguinaldo, P.G.; Anderson, C.; Bustamante, J.; Gelsinger, D.R.; Pastor, M.J.; Wright, J.; Márquez-Magaña, L.; Riggs, B. Near-peer STEM mentoring offers unexpected benefits for mentors from traditionally underrepresented backgrounds. *Perspect. Undergrad. Res. Mentor.* **2015**, *4*, 1–17. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5034940/ (accessed on 11 November 2015).
25. Taylor, L.; Mastrogiovanni, M.; Lakin, J.M.; Davis, V. Give and gain: Black engineering students as near-peer mentors. *J. Eng. Educ.* **2023**, *112*, 365–381. [CrossRef]
26. Kuh, G.D. *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter*; Association of American Colleges and Universities: Washington, DC, USA, 2008.
27. Linn, M.C.; Palmer, E.; Baranger, A.; Gerard, E.; Stone, E. Undergraduate research experiences: Impacts and opportunities. *Science* **2015**, *347*, 1261757. [CrossRef]
28. Chamely-Wiik, D.; Frazier, E.; Meeroff, D.; Merritt, J.; Kwochka, W.R.; I Morrison-Shetlar, A.; Aldarondo-Jeffries, M.; Schneider, K.R.; Johnson, J. Undergraduate research communities for transfer students. *J. Scholarsh. Teach. Learn.* **2021**, *21*, 193–225. [CrossRef]
29. Bowman, N.A.; Holmes, J.M. Getting off to a good start? First-year undergraduate research experiences and student outcomes. *High. Educ.* **2018**, *76*, 17–33. [CrossRef]
30. Gartstein, M.A.; Hancock, G.R. Professional development programs for women in academic science, technology, engineering, and math (STEM) fields: Enhancing retention and promotion. *Int. J. Gend. Sci. Technol.* **2021**, *13*, 43–63. Available online: https://genderandset.open.ac.uk/index.php/genderandset/article/view/760 (accessed on 4 September 2021).
31. Tsui, L. Effective strategies to increase diversity in STEM Fields: A review of the research literature. *J. Negro Educ.* **2007**, *76*, 555–581. Available online: http://www.jstor.org/stable/40037228 (accessed on 2 April 2007).
32. Pearson, J.; Giacumo, L.A.; Farid, A.; Sadegh, M. A systematic multiple studies review of low-income, first-generation, and underrepresented STEM-degree support programs: Emerging evidence-based models and recommendations. *Educ. Sci.* **2022**, *12*, 333. [CrossRef]
33. Slade, J.; Eatmon, D.; Staley, K.; Dixon, K.G. Getting into the Pipeline: Summer Bridge as a Pathway to College Success. *J. Negro Educ.* **2015**, *84*, 125–138. [CrossRef]
34. Tinto, V. Dropout from higher education: A theoretical synthesis of recent research. *Rev. Educ. Res.* **1975**, *45*, 89–125. [CrossRef]
35. Scriven, M. *Evaluation Thesaurus*, 4th ed.; SAGE Publications: New York, NY, USA, 1991.
36. Fitzpatrick, J.L.; Sanders, J.R.; Worthen, B.R. *Program Evaluation: Alternative Approaches and Practical Guidelines*, 3rd ed.; Pearson: London, UK, 2004.
37. Mertens, D.M.; Hesse-Biber, S. Mixed methods and credibility of evidence in evaluation. *New Dir. Eval.* **2013**, *138*, 5–13. [CrossRef]
38. Greene, J.C.; Benjamin, L.; Goodyear, L. The merits of mixing methods in evaluation. *Evaluation* **2001**, *7*, 25–44. [CrossRef]
39. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; Sage: Thousand Oaks, CA, USA, 2018.
40. Xu, Y.J. The experience and persistence of college students in STEM majors. *J. Coll. Stud. Retent. Res. Theory Pract.* **2018**, *19*, 413–432. [CrossRef]
41. Braun, V.; Clarke, V. Thematic analysis. In *APA Handbook of Research Methods in Psychology, Vol. 2: Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological*; Cooper, H., Camic, P.M., Long, D.L., Panter, A.T., Rindskopf, D., Sher, K.J., Eds.; American Psychological Association: Washington, DC, USA, 2012; pp. 57–71.
42. Saldaña, J.M. *The Coding Manual for Qualitative Researchers*, 3rd ed.; SAGE Publications: New York, NY, USA, 2015.

43. Hansen, M.J.; Palakal, M.J.; White, L. The importance of STEM sense of belonging and academic hope in enhancing persistence for low-income, underrepresented STEM students. *J. STEM Educ. Res.* **2024**, *7*, 155–180. [CrossRef]
44. Smith, K.C.; Geddis, D.; Dumas, J. The role of the HBCU pipeline in diversifying the STEM workforce: Training the next generation of drug delivery researchers. *Adv. Drug Deliv. Rev.* **2021**, *176*, 113866. [CrossRef] [PubMed]
45. Freeman, K.E.; Winston-Proctor, C.E.; Gangloff-Bailey, F.; Jones, J.M. Racial identity-rooted academic motivation of first-year African American students majoring in STEM at an HBCU. *Front. Psychol.* **2021**, *12*, 669407. [CrossRef] [PubMed]
46. Neal-Jackson, A. "Well, what did you expect?": Black women facing stereotype threat in collaborative academic spaces at a predominantly White institution. *J. Coll. Stud. Dev.* **2020**, *61*, 317–332. [CrossRef]
47. Bergen, N.; Labonté, R. "Everything is perfect, and we have no problems": Detecting and limiting social desirability bias in qualitative research. *Qual. Health Res.* **2019**, *29*, 557–566. [CrossRef]
48. Stewart-Williams, S.; Halsey, L.G. Men, women, and STEM: Why the differences and what should be done? *Eur. J. Personal.* **2021**, *35*, 3–39. [CrossRef]