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Preparing Future Leaders and Movers in Engineering and Computer Science: Outcomes and Insights from the FLAME S-STEM Program

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***Abstract*—This paper presents third-year outcomes of the Future Leaders and Movers in Engineering and Computer Science (FLAME) program at Norfolk State University, funded by the National Science Foundation S-STEM initiative. Drawing upon annual reports, external evaluation, and internal assessment data, the study examines recruitment, retention, leadership development, and STEM identity formation among participating students. Findings demonstrate a 91% retention rate and significant gains in technical confidence, leadership identity, and professional preparedness. Results highlight the effectiveness of integrating financial support, mentorship, and experiential learning to promote persistence and success in computing and engineering disciplines.**

I. Introduction

The Preparing Future Leaders and Movers in Engineering and Computer Science (FLAME) project was conceived to address a persistent challenge faced by many minority-serving institutions: bridging the gap between academic potential and professional leadership in STEM fields. Supported by the National Science Foundation's Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program, FLAME integrates financial assistance with structured mentorship, research training, and leadership development activities to foster student success in Computer Science, Information Technology, Electrical Engineering, and Optical Engineering majors.

Now in its third year (2024–2025 cycle), FLAME supports 20 active scholars, building on the momentum of its first two cohorts. The program seeks to (1) provide economic access for academically qualified low-income students; (2) improve recruitment, retention, and graduation rates within CSET (Collège of Science, Engineering, and Technology) departments; and (3) create a pipeline of future leaders and innovators through experiential learning and role model exposure.

This paper synthesizes findings from three complementary sources—the official NSF annual report [1], the external evaluation [2], and the internal assessment [3]—to provide a multi-perspective analysis of FLAME's third-year performance. The discussion addresses key evaluation questions:

1) To what extent does FLAME improve recruitment and retention of academically talented, low-income STEM students?
2) How does participation in FLAME influence students' leadership development and STEM identity?
3) What programmatic elements contribute most significantly to student success and persistence?

II. Background and Literature Review

A. The S-STEM Framework

The NSF's S-STEM program aims to support the education and retention of low-income, academically talented students pursuing STEM degrees by linking financial aid to structured support systems. Programs such as FLAME extend this mission by creating holistic learning ecosystems that combine economic support with academic enrichment and professional identity formation.

Prior research on S-STEM initiatives has identified three core success factors: (1) intentional mentorship and role model engagement [4][5][6]; (2) experiential learning opportunities such as internships and research placements [7]; and (3) community-building activities that reinforce belonging and self-efficacy among underrepresented students [8]. The FLAME program's design reflects each of these elements, with added emphasis on leadership training and professional communication skills within the context of an HBCU.

B. Leadership Development and STEM Identity

Leadership training in STEM education is increasingly recognized as a critical factor in career success [8][9]. Programs that embed leadership modules, networking opportunities, and exposure to diverse role models enhance students' capacity for team management, project coordination, and strategic thinking. FLAME builds on this literature by cultivating leadership through weekly seminars, public presentations, and event planning (e.g., the annual Spring Banquet and Fall Retreat).

Moreover, STEM identity development is a central theoretical lens for the FLAME project. According to Carlone and Johnson [10], STEM identity is constructed through recognition, performance, and competence within scientific communities of practice. For FLAME students, identity formation occurs via active participation in research, mentoring, and professional exposure opportunities such as the Black Engineer of the Year (BEYA) conference and industry internships.

C. Experiential Learning in HBCU Contexts

Experiential learning theory [11][12][13], posits that learning occurs through reflection on experience. Vygotsky's social constructivism adds a sociocultural dimension, asserting that learning is mediated through social interaction and scaffolded by mentors. For HBCUs, these frameworks are particularly relevant because they emphasize contextual learning within supportive communities that validate students' backgrounds and experiences.

FLAME's experiential activities align closely with these frameworks: Python bootcamps, research assistantships, and site visits serve as hands-on learning experiences that bridge theory and practice while building leadership capacity. These activities also address a critical gap in STEM education by linking technical skills with soft skills such as communication, adaptability, and self-reflection.

III. Theoretical Framework

The FLAME program is guided by two intersecting frameworks: **Vygotsky's Social Constructivism** [12][13][11] and **Role Model Theory** [14][6][5]. Together, they inform the program's approach to developing scholars' academic, technical, and leadership competencies.

A. Social Constructivism and Experiential Learning

Vygotsky's social constructivist theory posits that learning is a socially mediated process in which knowledge is constructed through interaction with more experienced peers or mentors [12]. Within FLAME, this model is operationalized through the integration of seminars, workshops, and research experiences that allow students to co-construct knowledge while developing self-regulatory skills. The experiential learning process is further supported by structured reflection activities, such as portfolio development and peer mentoring. These artifacts document students' growth as they progress through the program's phases—from awareness and academic adaptation to technical mastery and leadership identity.

B. Role Model and Mentorship Theory

Role model theory [4][5][6] conceptualizes learning through reference groups—individuals whose knowledge, behaviors, and values guide learners' professional formation [5]. FLAME scholars are deliberately paired with academic and industry role models to strengthen STEM identity. These relationships occur through guest lectures, lab tours, and the annual FLAME banquet featuring distinguished speakers such as Dr. Carl McCants (Defense Advanced Research Projects Agency (DARPA)) and Dr. Kato Mivule (Department of Defense, Data Science Lead).

Empirical evidence from Year 3 interviews indicates that scholars who interacted regularly with STEM professionals demonstrated greater confidence in their academic and career trajectories, validating the role model construct as a central mechanism of the program.

IV. Program Design and Implementation

The FLAME project was designed around three overarching goals, consistent across all annual reports and evaluations:

1) **Establish a scholarship program** that develops future industry and academic leaders in Computer Science (CS) and Engineering (EGR).
2) **Improve baseline metrics**—including the number of applicants, freshman retention, and four-year graduation rates—by at least 10
3) **Cultivate self-identification** among students as scientists and engineers through exposure to professionals and leadership experiences.

A. Program Activities

To achieve these goals, FLAME operationalizes a multi-layered structure that integrates financial, academic, and professional development components:

- **Recruitment and Scholarship Support:** The program recruited four new scholars in Year 3, expanding to 20 active participants across three cohorts. Selection involved academic merit, financial need verification, and major alignment in CS or EGR.
- **FLAME Leadership Seminar:** A bi-weekly forum emphasizing leadership, technical writing, and oral communication. Scholars developed professional portfolios containing resumes, technical skills pages, and graduate school plans.
- **Experiential Learning:** Students participated in research assistantships, internships at Intel, Northrop Grumman, and Jefferson Lab, and hands-on workshops including the Python Distinguished Lecture Series.
- **Community-Building Events:** Scholars attended the annual BEYA Conference (Baltimore, 2025), Fall Retreat (Jefferson Lab tour), and Spring Banquet featuring keynote industry leaders.
- **Portfolio Development:** Students transitioned from basic Word-based resumes to web-based professional portfolios using Google Sites.

B. Institutional Integration

The FLAME project leverages existing NSU infrastructure, including the Writing Center, Career Services, and the College of Science, Engineering, and Technology's (CSET) internship partnerships. It also complements institutional initiatives such as the STARS tutoring program and Summer Bridge math enrichment.

This alignment ensures sustainability beyond NSF funding, embedding the program's leadership and mentorship structures into departmental operations.

Figure 1 presents a conceptual overview of the FLAME program, illustrating the alignment between program inputs, core activities, theoretical grounding, and measured student outcomes. The framework highlights how scholarship support, mentoring, and experiential learning activities are intentionally structured to promote technical skill development, leadership

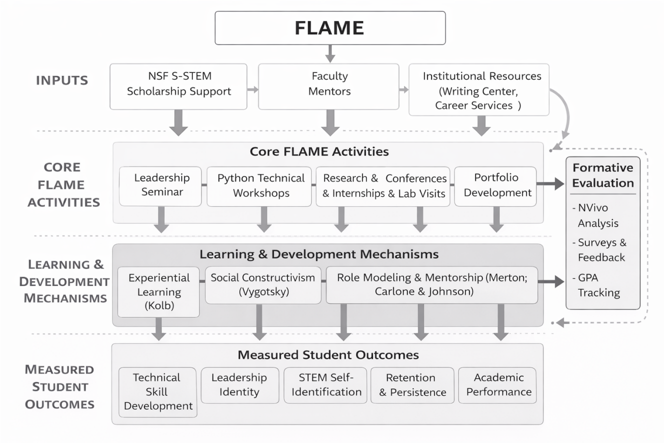

Figure 1. Conceptual framework of the FLAME program illustrating inputs, core activities, theoretical grounding, and measured student outcomes.

identity, and STEM persistence. Formative evaluation mechanisms, including surveys, academic performance tracking, and qualitative analysis using NVivo, provide ongoing feedback to inform continuous program improvement.

V. Methodology

A. Mixed-Methods Approach

The Year 3 evaluation employed a mixed-methods design integrating quantitative (GPA, retention, participation rates) and qualitative (interviews, portfolio content analysis) data to assess progress toward stated objectives.

- **Quantitative Data:** GPA data from institutional records and retention statistics across Cohorts 1–3 were analyzed. Sixteen of seventeen students renewed scholarships, and the program achieved a 91% retention rate for Year 3.
- **Qualitative Data:** Twenty semi-structured interviews were conducted with scholars from all cohorts via video conferencing in September 2025. Interviews captured students' perceptions of leadership, STEM identity, and program impact.
- **Documentary Analysis:** Portfolios and workshop evaluations were reviewed to triangulate student-reported growth with evidence of skill acquisition.

B. Data Analysis

NVivo 14 [15] software was used to analyze qualitative data derived from open-ended student reflections associated with two Python technical workshops. Responses to the question "List your three main learning outcomes from the workshop" were examined using NVivo's word frequency and visualization tools to identify salient themes related to technical skill development and learning outcomes. The analysis included responses from twelve students in Workshop 1 and seven students in Workshop 2. A word cloud was generated to visually represent dominant themes, with the most frequently occurring terms including Python, Learning, Code, and Programming.

This focused analysis complements broader formative evaluation activities conducted as part of the FLAME program, which include reflective artifacts and seminar-based self-assessments; however, the results presented here are based specifically on workshop-related student responses.

Qualitative themes identified through this analysis were examined in relation to quantitative academic indicators, such as student persistence and GPA trends, to assess consistency between reported learning outcomes and observed academic engagement. This complementary comparison provides contextual support for the interpretation of findings and illustrates the relationship between experiential learning activities and students' technical confidence and leadership development.

Limitations

The qualitative analysis presented in this study is based on responses to a single open-ended question and reflects a limited sample size associated with two workshop offerings. As such, findings are intended to provide descriptive insight into student learning outcomes rather than comprehensive thematic saturation.

Table I
FLAME cohort enrollment summary

Cohort	Year	Students	Retained	Retention
Cohort 1	2022	7	5	71%
Cohort 2	2023	12	10	83%
Cohort 3	2024	5	5	100%
Total	–	**24**	**20**	**91%**

VI. Recruitment and Retention Outcomes

A. Recruitment Success

The third year of FLAME demonstrated effective recruitment of academically talented, financially eligible students (Table I). The project's digital presence—through flamescholar.com and the AI & ML Secure Portal—streamlined applications and increased visibility to incoming majors.

Figure 2 shows the distribution of student GPAs during the 2024–2025 academic year. Only one student's GPA fell below 3.0, indicating strong academic engagement despite the rigor of engineering and computer science curricula.

Students with higher classification demonstrated greater self-regulation and integration of leadership skills, supporting the theoretical model's hypothesis that experiential engagement reinforces academic persistence.

B. Academic Performance

VII. Experiential Learning and Leadership Development

Experiential learning was central to the FLAME program's third-year activities. Students participated in two *Python Technical Workshops*, a *Fall Retreat* at Jefferson Lab, and a *Spring Banquet* featuring STEM professionals. These experiences were explicitly tied to the program's social constructivist model: each activity represented a scaffolded learning event enabling scholars to connect classroom theory with real-world applications.

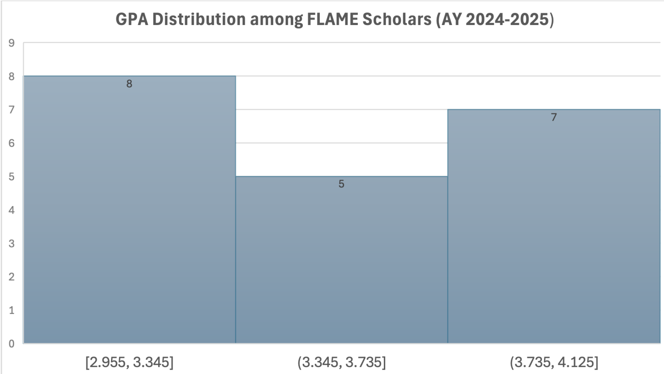

Figure 2. GPA distribution among FLAME scholars (2024–2025).

The two-part Python series covered variables, control structures, data types, debugging, and object-oriented programming (OOP). Scholars demonstrated significant conceptual improvement across sessions—71% reporting increased understanding by session two. This growth was further evidenced by the technical pages in their portfolios.

Figure 3 captures the thematic focus of students' learning outcomes. The open-ended question 'List your three main learning outcomes from the workshop' was analyzed. A graphical representation of student learning outcomes is illustrated in the accompanying word cloud. The four most popular words, based on students' responses, were Python, Learning, Code, and Programming. The thematic analysis was conducted using NVivo qualitative analytical software. The responses of twelve students from Workshop 1 and seven students from Workshop 2 were explored with NVivo.

In the leadership dimension, qualitative interviews revealed consistent growth in self-efficacy, communication, and teamwork. Students articulated that the *Spring Banquet* and *BEYA Conference* expanded their awareness of career pathways and provided concrete examples of success from minority professionals in STEM.

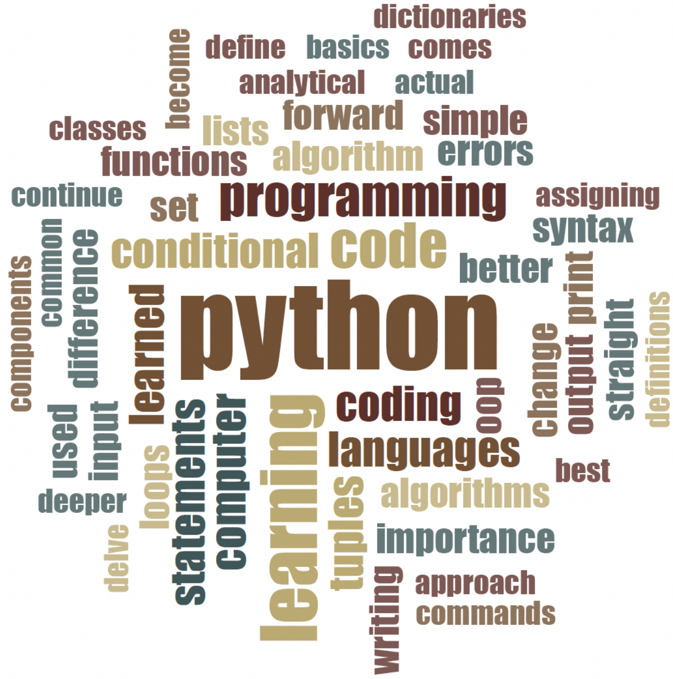

Figure 3. Themes emerging from Python workshop evaluations (NVivo word cloud).

Table II
INSTITUTIONAL AND HUMAN RESOURCE IMPACTS OF FLAME (2024–2025)

Impact area	**Indicators**	**Outcomes**
Faculty engagement	Active faculty mentors	Six faculty from Computer Science and Engineering participated
Peer mentorship	Student-led mentoring initiatives	Peer pairing across cohorts established
Writing proficiency	Portfolio development and Writing Center sessions	90% participation; improved resumes and essays
Retention support	Advising models and seminars	91% persistence across cohorts

VIII. Impact on Human and Institutional Resources

A. Human Capital Development

Through conferences, workshops, and mentorship, scholars developed transferable skills including project management, research writing, and technical documentation. They also enhanced interpersonal competencies such as collaboration, professionalism, and adaptive leadership.

A notable result was the creation of a **sustained peer mentorship structure** within FLAME. Senior scholars began mentoring lower cohorts, acting as "internal role models" within the community. This horizontal leadership dynamic reinforced belonging and built continuity across cohorts.

B. Institutional Strengthening

Institutionally, FLAME leveraged existing NSU resources (Writing Center, Career Services) and influenced policy discussions around retention and advising models. Faculty engagement increased across departments, with six faculty and staff directly supporting FLAME activities in Year 3. The program's infrastructure—including portfolio workshops and seminar templates—is now being adapted for broader departmental use. (See Table II)

IX. Broader Educational and Societal Impacts

Beyond academic outcomes, FLAME has influenced students' perception of STEM as a civic and societal enterprise. Interviews revealed scholars expressing motivation to "give back" to their communities through technology education and entrepreneurship.

At the societal level, the program presented its outcomes at multiple venues, including the **17th International Con-**

ference on Education and New Learning Technologies (EDULEARN25, Spain) and the **QEM/AIR S-STEM Research Hub Conference (Atlanta, GA)**. The dissemination of FLAME findings demonstrates how HBCUs can model culturally responsive, leadership-focused STEM pathways.

X. Assessment and Evaluation Findings

The external evaluator conducted a thematic analysis of FLAME's third-year data, identifying the following key outcomes:

1) **High Retention and Persistence:** 20 of 22 students continued in STEM majors (91
2) **Leadership Competency Growth:** Self-assessment and mentor feedback indicated significant improvement in communication and organizational leadership.
3) **Enhanced STEM Identification:** Scholars increasingly described themselves as "engineers" or "scientists" rather than "students," demonstrating identity internalization.
4) **Expanded Professional Networks:** Increased participation in conferences and lab visits broadened professional exposure.
5) **Portfolio Maturation:** Transition to web-based portfolios improved visibility and digital literacy.

NVivo analysis revealed that 42% of responses aligned with "Leadership Development," 28% with "Technical Skills," and 30% with "Community and Belonging."

XI. Discussion

The synthesis of FLAME's Year 3 findings underscores the effectiveness of coupling financial aid with leadership and experiential learning. Scholars' reflections confirmed the synergistic relationship between hands-on practice and identity development.

Three lessons emerge:

1) **Mentorship is Transformative:** Structured mentor–scholar interactions, whether vertical (faculty–student) or horizontal (peer–peer), are the backbone of STEM identity formation.
2) **Leadership Emerges Through Practice:** Exposure to real-world challenges and professional forums (e.g., BEYA, Jefferson Lab) transforms technical knowledge into applied leadership.
3) **Institutional Ecosystems Matter:** Embedding support structures within existing university frameworks ensures program sustainability.

The FLAME model demonstrates that at HBCUs, leadership cultivation can occur alongside academic achievement when mentorship, reflection, and experiential opportunities intersect.

XII. Lessons Learned and Recommendations

- **Integrate Reflection Early:** Encourage students to document growth from the first semester through guided portfolio milestones.
- **Strengthen Alumni Linkages:** Graduating scholars should serve as external mentors to new cohorts, creating a cyclical mentorship loop.
- **Enhance Faculty–Industry Collaboration:** Continue to involve industry partners in technical workshops and capstone mentoring.
- **Formalize Leadership Curriculum:** Transform FLAME seminar content into a one-credit leadership course for scalability across departments.
- **Increase Dissemination Channels:** Expand presentations at ASEE and SIGCSE to share the HBCU-based leadership framework with the wider STEM education community.

XIII. Conclusion

The FLAME program at an HBCU exemplifies how S-STEM initiatives can evolve beyond financial support into holistic leadership pipelines. Through social constructivist design and intentional role modeling, FLAME scholars have demonstrated academic persistence, professional growth, and a deepening sense of STEM identity.

With its measurable success in recruitment, retention, and leadership development, the FLAME framework offers a replicable model for peer institutions seeking to diversify the STEM workforce. As the program advances toward 2028, continued evaluation will focus on longitudinal tracking of graduates and integration of AI-driven learning analytics to personalize mentorship.

Acknowledgment

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