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Three Years of STEM Identity Growth in a Hybrid NASA Program: Pre- and Post-Program Perception Trends from High School Students

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Introduction

This research to practice paper reports three years of pre/post findings from a Future Aerospace and Mathematics Academy (FAMA) for High School students, a hybrid NASA Minority University Research and Education Project (MUREP) Aerospace Academy (MAA) program delivered by a university in central Texas in partnership with Johnson Space Center, two community centers, and five nearby school districts.

FAMA 3: High School IDEAS (Innovation, Discovery, Exploration in Aerospace and Science) is built on a conceptual framework from two previously funded action research projects to examine programmatic impacts in informal learning settings. It engaged historically underrepresented and underserved high-school students through quarterly micro-credentials (digital badges), live webinars with NASA SMEs, "Saturday Deep Dive" hands-on skill development sessions, near-peer mentoring, family engagement, field trips, and annual residential STEM camp aligned to rotating themes (Year 1: Earth Observations; Year 2: Lunar Exploration; Year 3: Aeronautics/Acoustic Damping). Students completed at least 60 hours of activities annually and a NASA-aligned project-based design capstone. This program also responded to longstanding national calls to strengthen STEM preparation and broaden participation through sustained K–12 engagement [1].

Preliminary trends indicate the clearest gains in STEM networking with reflective identity indicators trending upward, while NASA research awareness and perceived college STEM capability remained relatively stable across timepoints. The greatest year-over-year improvements were among students who completed multiple micro-credentials and participated in site visits. We share the program's logic model, survey instrument, and early lessons on integrating digital badges, near-peer mentoring, and family sessions to strengthen STEM identity and inform scalable NASA-aligned pathways.

Background & Programmatic Foundation

FAMA 3: HS IDEAS has a strong foundation in the prior NASA MUREP Aerospace Academy (MAA) programs: FAMA 1 and FAMA 2. The more recent FAMA 2 (2018–2020) met its objectives, reaching approximately 3,063 middle school students, family members, and teachers over the two-year award period, while also building district capacity, particularly within the school district in which the university sits, to sustain high-impact components beyond the grant. FAMA 2 delivered culturally relevant, NASA-based STEM experiences emphasizing algebraic thinking and the engineering design process, leveraging NASA resources and MathWorks mathematics lessons. Two consistently high-impact elements were the NASA Family Backpack (STEM kits adapted for and delivered directly to families to support student engagement) and

FAMA Summer Camps, reinforcing the program's family-engagement and experiential-learning model.

Prior research from the FAMA team demonstrated that participation in engineering-focused camp experiences enhances family engagement in STEM discussions and strengthens students' understanding of engineering careers and the design process [2], [3]. These insights inform the design of *HS IDEAS*, which purposefully integrates family and community engagement to achieve sustained impact. More specifically, FAMA 2 informed four implementation priorities carried forward into FAMA 3: (1) structured professional development for incoming teachers, (2) sustained district-level leadership engagement to support scalability and long-term continuity, (3) measurable recruitment and retention goals for historically underserved and underrepresented students, and (4) stronger family engagement strategies during STEM learning sessions. Building on these accomplishments and partnerships, and on Texas State's additional experience serving high school students through initiatives such as PEACE GEMS (Pre-Engineering and Career Exploration for Girls Interested in Engineering, Math and Science), FAMA 3 extends the model to high school youth across five partnering districts, adds college exploration and near-peer mentoring, and expands opportunities for interaction with STEM professionals and industries. These priorities were especially important given ongoing demographic shifts in the U.S. school-age population [4].

Goals & Objectives

HS IDEAS pursues five integrated objectives: (1) sustain STEM skill-building and experiential learning across the academic year and summer; (2) increase interaction with NASA-aligned subject matter experts and near-peer mentors; (3) strengthen college and workforce STEM pathways through readiness and career exploration; (4) orient and empower families as STEM stakeholders through ongoing engagement and college-navigation supports; and (5) provide continued professional development and implementation support for instructional staff to deliver culturally responsive, technology-rich STEM learning experiences with fidelity across sites. This emphasis on networking and professional exposure also aligns with research highlighting employability skills as an important outcome for STEM students [5].

Conceptual and Measurement Framework

HS IDEAS is grounded in constructivist, social constructivist, and constructionist perspectives that position learning as active, collaborative, and situated in authentic practice. In this model, students build knowledge through hands-on making and dialogue with peers, mentors, and families in culturally meaningful contexts. To operationalize identity-focused outcomes, we used Collins' (2018) Black Student STEM Identity (BSSI) framework, which conceptualizes STEM identity across four interrelated dimensions: Reflective Identity (representation/mentor match), Competence/Ability, Value/Interest, and Assimilation/Belonging [6]. Our survey mapped items to these dimensions and extended the external context to include Networking behaviors and NASA Awareness, reflecting program priorities (SME interactions, site visits, and micro credentials). This alignment enabled us to examine whether cohort-level changes in identity, belonging, values, capabilities, and STEM social capital were consistent with the program's theory of change. The program also builds on prior work using engineering robotics as a context for applied mathematics learning and STEM motivation [7].

Survey Design Theoretical Framework

The *HS IDEAS* self-perception survey was designed using Collins' Black Student STEM Identity (BSSI) model as a guiding theoretical framework to explore how participants perceive their STEM identity, motivation, and sense of belonging within culturally contextualized learning environments [6]. The BSSI model conceptualizes STEM identity as a dynamic and cyclical process shaped by the reciprocal relationship between the learner's internal environment (family, community, and culture) and external environment (school, mentors, professional networks, and workplace contexts).

At the core of the BSSI model are four interrelated constructs: Reflective Identity, Competence/Ability, Value/Interest, and Assimilation, each of which was operationalized as corresponding survey prompts. These dimensions assess students' developing STEM identity through culturally and experientially relevant questions that align with the HS IDEAS program's NASA-based curriculum and mentorship model.

Reflective Identity: Items such as Q3.2 and Q3.2.1 ("How often do you get to work or meet with STEM mentors or teachers of the same race/gender as you?") and Q3.9 ("To what extent do you believe that personal and professional differences may impact research and performance expectations between mentors and mentees?") capture students' awareness of representation and their relational connection to mentors and role models who share similar identities.

Competence/Ability (or Capability): Q3.8 ("To what extent do you feel capable of going to college for STEM?") measures students' perceived self-efficacy, confidence, and agency to pursue STEM degrees—mirroring Collins' emphasis on competence as a determinant of identity persistence.

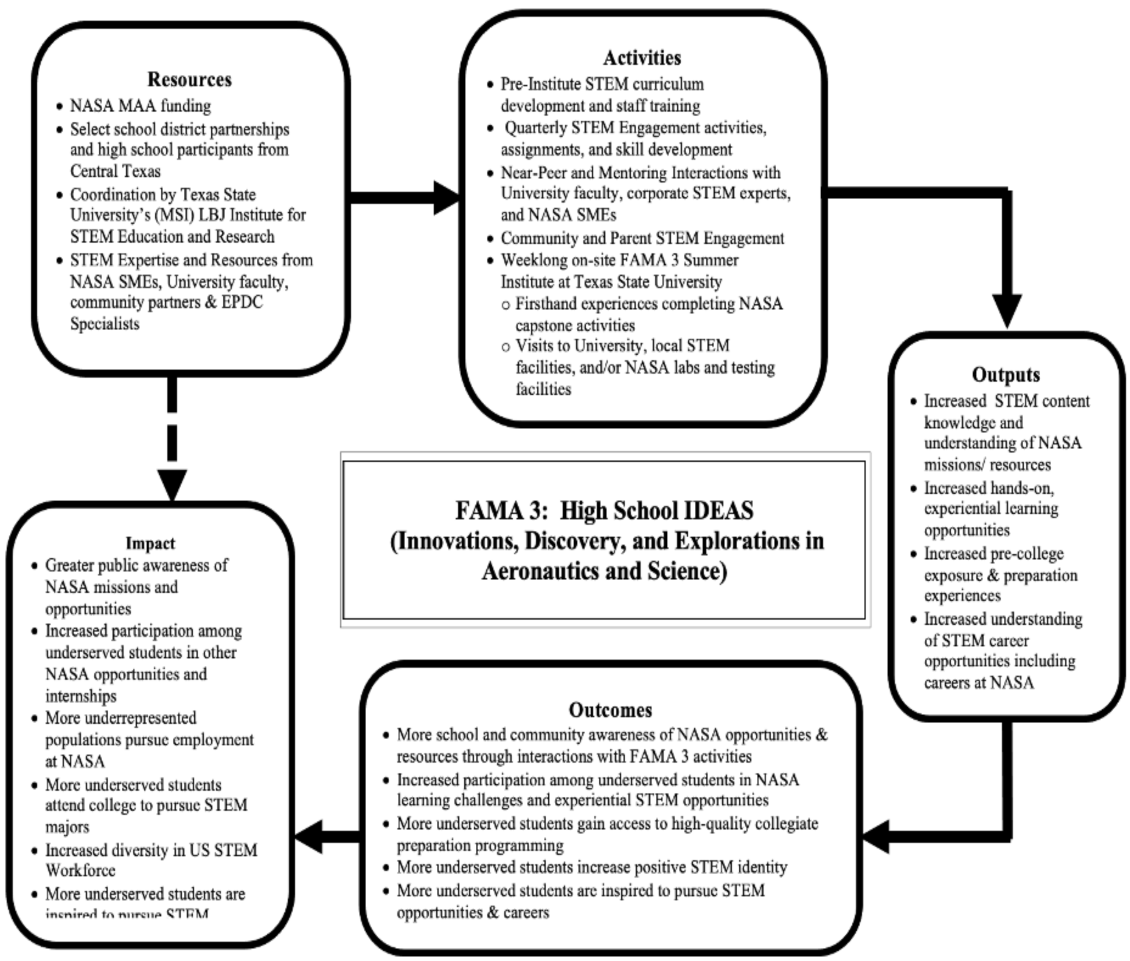
Value/Interest: Items such as Q3.1 ("To what extent would you want to work at NASA or another STEM industry company?") and Q3.6 ("To what extent has this HS IDEAS program positively affected your perspective and goals toward a STEM degree or job?") probe intrinsic motivation and perceived relevance of STEM to personal goals and community values.

Assimilation (or Belonging): Q3.3 ("To what extent do you feel like you would belong and/or feel comfortable working at NASA?") reflects students' perceptions of inclusion within STEM spaces and their ability to maintain authenticity while participating in those environments. Building on the BSSI framework, the *HS IDEAS* survey also incorporated Networking (Q4.3–Q4.4) and NASA Awareness (Q4.6) as program-specific extensions of the external context dimension. These additional constructs recognize that access to professional networks, mentors, and awareness of real-world STEM research (e.g., NASA missions) are key to strengthening Reflective Identity and Value/Interest. Networking questions evaluate the frequency and quality of interactions with STEM professionals, while Awareness items assess students' connection to NASA's mission and the visibility of authentic STEM work.

Together, these constructs form a comprehensive evaluation structure rooted in culturally responsive theory and authentic STEM engagement. Consistent with constructivist and social constructivist foundations [8], [9], [10], this design emphasizes identity development as an active, socially mediated process of meaning-making. The integration of Collins' BSSI model ensures that measures of STEM identity are not limited to academic self-concept but instead capture the lived, intersectional experience of students as emerging STEM learners and future professionals.

Evaluation Framework: Theory of Change (Logic Model)
Achievement of the outcomes for the *HS IDEAS* project was systematically evaluated through the implementation of an evaluation plan tied to the project's specified objectives, grounded in the logic model (See Fig. 1) and evidence-based evaluation practices. *HS IDEAS* activities and outputs were aligned with NASA's annual performance indicators and agency-wide priorities. Outcomes and impacts were strategically aligned with NASA's Goal 2/Objective 2.4 to advance the Nation's STEM education and workforce pipeline.

Figure 1. FAMA 3: High School IDEAS Logic Model



By increasing the number of historically underrepresented students and their families and providing authentic, firsthand STEM experiences, this program aimed to contribute to NASA Goal 2. Outputs provide the targeted elements for evaluating short-term goals. These short-term goals align with NASA's annual performance indicators ED-17-2, ED-17-4, and ED-17-5. Outcomes also provide targeted elements to evaluate the effectiveness of the proposed program towards long-term goals, specifically regarding the overall project impact and building the interest, skills, and knowledge necessary for K-12 students to pursue STEM experiences aligned with NASA mission content.

Implementation Priorities
The four priorities of *HS IDEAS* are grounded in the established STEM education literature, which emphasizes teacher capacity building, systemic leadership engagement, equity-centered recruitment, and authentic family partnerships.

1. **Structured Professional Development for Incoming Teachers.** Sustained and structured professional development (PD) is widely recognized as a critical driver of teacher confidence, instructional innovation, and student outcomes in STEM fields. Research on effective STEM professional development emphasizes hands-on engagement, alignment with curriculum standards, and opportunities for teachers to design and reflect on their instructional practice [11], [12]. For early-career or incoming teachers, structured PD that integrates engineering design, culturally responsive pedagogy, and real-world STEM contexts improves both self-efficacy and retention [19]. Within the *HS IDEAS* model, teacher professional development builds directly on these findings, providing guided exposure to NASA missions, collaborative curriculum design sessions, and embedded coaching from experienced mentors. This approach mirrors recent work by Zizka, McGunagle et al. [13], who demonstrate that STEM programs grounded in authentic, community-based engagement enhance both teacher learning and program sustainability.

2. **Sustained District-Level Leadership Engagement.** Long-term scalability of STEM initiatives depends not only on teacher preparation but also on district-level leadership engagement that institutionalizes program components beyond grant cycles. Prior studies underscore that administrative buy-in and system-level support are key to sustaining programmatic innovations and ensuring continuity for underrepresented learners [14], [15]. District leaders play a pivotal role in aligning STEM initiatives with local priorities, integrating resources, and ensuring teacher participation through policy and scheduling support. *HS IDEAS* developed accountability mechanisms for tracking student recruitment and progression across multiple districts. This approach is consistent with distributed leadership frameworks in education reform [16].

3. **Recruitment and Retention of Historically Underserved Students**. Persistent underrepresentation of Black, Latino, and economically disadvantaged youth in STEM pathways continues to challenge equity and workforce diversity goals [1], [3]. Research emphasizes that effective recruitment and retention efforts must combine early exposure, representation, and identity-affirming experiences [6], [17]. The program integrated Collins' Black Student STEM Identity (BSSI) framework to assess participants' evolving self-perceptions of belonging, competence, and motivation, and to address both race and gender as central factors in STEM identity formation [6]. By embedding these constructs in both program design and evaluation, *HS IDEAS* positions itself within an emerging body of literature advancing culturally responsive evaluation of STEM equity interventions [6], [18].

4. **Strengthening Family Engagement in STEM Learning**. Family engagement continues to emerge as one of the strongest predictors of youth persistence in STEM learning, particularly among underrepresented populations [16], [20]. Research demonstrates that culturally grounded family STEM experiences—particularly those embedded in everyday life and supported through parent–child interactions—enhance motivation and are positively associated with students' STEM self-efficacy [20], [21]. *HS IDEAS* builds on this evidence by deepening family involvement through active engagement alongside their students in the Saturday Deep Dives and in special sessions and resources on financing and supporting students through college. These strategies reflect a social constructivist approach to learning, in which knowledge is co-constructed through shared experiences and dialogue among learners, mentors, and families [9]. In alignment with recent literature, the program positions families not merely as supporters but as co-learners and advocates in the STEM learning ecosystem, thereby strengthening both academic and cultural continuity.

These elements reflect best practices in sustaining STEM pathways, particularly in communities historically excluded from such opportunities. By uniting them with NASA's experiential learning framework and culturally responsive evaluation tools, *HS IDEAS* advances a scalable, research-informed model for equitable access to STEM and for identity development.

Research Question(s)

Guided by the BSSI framework and the project logic model, we examined:

- **RQ1.** To what extent does participation in the HS IDEAS program relate to cohort-level differences in students' STEM identity, belonging, value, capability, networking, and NASA awareness from program entry (pre) to program exit (post)?
    - **RQ1a.** Which specific networking and reflective identity indicators exhibit the largest pre–post differences?
    - **RQ1b.** Which program experiences do students identify as most valuable for shaping STEM engagement (qualitative)?
- **RQ2** (Mechanism check). Are identity/belonging/value constructs associated with networking behaviors after controlling for time point?

Methods

A brief self-perception survey administered at program entry and exit each year assessed capability (college STEM), value/motivation (NASA/STEM careers), belonging/comfort at NASA, reflective identity (exposure to mentors by race/gender), awareness of NASA research, and networking behaviors (talking/working with STEM professionals), with open-ended prompts on most/least valuable experiences. Quantitative analyses summarized distribution shifts on ordinal scales (item-level and construct composites) using independent-sample pre–post comparisons (2023 vs. 2025), estimated standardized differences (Hedges' g), and examined mechanism-consistent associations among constructs; open-ended responses were thematically coded to contextualize patterns. Qualitative responses are thematically coded to contextualize patterns (e.g., which experiences most influence belonging or networking).

Program Participation Context (Recruitment & Selection)

HS IDEAS was designed to serve high school students from economically disadvantaged communities, with targeted recruitment of Hispanic students and other historically underrepresented populations in STEM. The program aimed to engage at least 100 students annually across partnering districts, with students completing a minimum of 60 hours of STEM engagement per year through quarterly activities (fall/winter/spring), a 30-hour residential summer camp, and additional optional/make-up experiences. Recruitment and selection procedures prioritized equitable representation across districts (approximately 25 students per district), application-based selection using a rubric and blind scoring by multiple reviewers, and continuity across years (students completing a prior year were invited with priority for subsequent years).

Analytic Sample and Representativeness

Although program reach across touchpoints exceeded the number of completed surveys, the present analyses rely on completed self-perception surveys collected at entry (2023) and end-of-cycle (2025). Consequently, the participant snapshot presented in Table 1 (Appendix B) describes the survey respondent subsample rather than the full program population. This difference between program participation and survey completion underscores that findings should be interpreted as trends among survey respondents and motivates future cycles to integrate survey administration into required milestones (e.g., end-of-webinar, end-of-camp) and to link survey completion to participation tracking systems.

Across the three-year FAMA initiative, students completed the self-perception survey at program entry and exit. The current dataset contained 52 survey records. To reduce partial-response bias, primary analyses used only completed surveys, yielding n = 32: pre (2023) n = 20 (out of 33 submitted) and post (2025) n = 12 (out of 15 submitted).
The sample reflects expected developmental progression across timepoints: the 2023 pre-group was primarily freshmen and sophomores (75%), while the 2025 post-group was primarily seniors (66.7%). Hispanic/Latino(a) identity was reported by 60.0% (2023) and 83.3% (2025) of respondents. Gender distribution was mixed at both timepoints (2023: 45.0% girl/woman, 40.0% boy/man; 2025: 58.3% girl/woman, 33.3% boy/man). Race was reported as primarily White at both time points (2023: 70.0%; 2025: 75.0%).

Research Perspective (Familia)

In the FAMA programming, culturally relevant methods for engaging students and families were grounded in the centrality of conversations as relational and pedagogical practices. Drawing on social learning theory, facilitators prioritized intentionally creating safe spaces in which participants could share stories, experiences, and aspirations related to STEM learning and future pathways. As Guajardo et al. [22] argue, learning is fundamentally mediated through relationships built via dialogue and storytelling. Within FAMA, these interactions were best understood through the concept of *pláticas*, which move beyond conventional conversation to represent a culturally situated practice shaped by listening, inquiry, and collective meaning-making [23]. Pláticas allowed facilitators to position students and families not as passive recipients of information about STEM or college access, but as co-constructors of knowledge whose lived experiences were legitimate sources of insight.

Pláticas functioned as a methodological and pedagogical tool to bridge personal, cultural, and academic knowledge. Fierros and Delgado-Bernal [24] emphasize that *platicando* enables participants to weave together their personal narratives with academic discourse, a process that was particularly salient in FAMA given the program's emphasis on family engagement and community-based learning. Through structured yet flexible conversations, participants articulated their hopes, concerns, and prior experiences with schooling, while facilitators gained critical cultural knowledge that informed program design and implementation. These Saturday sessions supported the development of trust and affirmed that participants' stories had value, aligning with Community Learning Exchanges (CLE) pedagogy's emphasis on safe environments, storytelling, and relationship-building as foundations for sustainable learning [22].

Consistent with Freire's [25] assertion that dialogue is central to transformative and liberatory education, the use of pláticas in FAMA fostered critical consciousness and agency among participants. Framing questions in culturally responsive and artful ways enabled facilitators to support reflection on community contexts and systemic barriers, while also promoting collective problem-solving around STEM access and opportunity. In this way, conversations were not merely communicative acts but culturally relevant interventions that nurtured relationships, honored community knowledge, and positioned students and families as active agents in shaping their educational trajectories [22].

Research Approach & Treatment

HS IDEAS examined STEM as a complex, multi-component intervention aligned to the project logic model in which outcomes were expected to emerge through repeated engagement cycles and cumulative participation over three years. The "treatment" consisted of an integrated hybrid model delivered each term (fall/winter/spring) and reinforced through an annual residential camp and capstone experience. The *HS IDEAS* curriculum, structured to promote grade-appropriate exploration of core science and mathematics concepts, integrates engineering and science practices. Each program cycle was organized around the annual NASA-related theme, ensuring authentic relevance and exposure to real-world STEM applications. Each theme introduces students to engineering design principles through inquiry, modeling, and hands-on experimentation aligned with NASA missions and STEM career pathways. This thematic, constructivist, and constructionist integration supports the development of both conceptual understanding and identity as STEM learners, which are core objectives of the *HS IDEAS* initiative.

Core components included: Self-paced NASA EPDC micro-credentials, Subject Matter Expert (SME-led) webinars, quarterly hands-on Saturday Deep Dives, near-peer mentoring and learning communities, portfolio-based documentation of milestones and artifacts, family engagement sessions focused on college and career navigation, and ongoing professional development for instructional staff to support culturally responsive implementation (See Fig. 2).

Figure 2. HS IDEAS Program Flyer Depicting Core Components

Data Collection & Analysis

Survey Validation & Reliability. The *HS IDEAS* self-perception survey was developed using the Collins' Black Student STEM Identity (BSSI) model [6] as the primary framework to ensure content and construct validity. Survey items were mapped to the four dimensions of the BSSI and extended to include Networking and NASA Awareness to capture authentic STEM exposure and mentorship experiences (see Survey Design Theoretical Framework & Appendix C). This direct theoretical mapping followed a *content validity-by-design* approach (Haynes et al., 1995), ensuring a priori alignment between constructs and measures [26]. To establish face validity, the instrument underwent expert review by the research team's STEM education faculty, a NASA education specialist, and a program evaluator, who confirmed its construct accuracy, cultural responsiveness, and age appropriateness. Feedback-informed revisions for clarity, inclusivity, and consistency across items. The survey was piloted during PEACE GEMS to assess internal coherence and respondent comprehension. Response patterns showed consistency within construct clusters (e.g., Reflective Identity and Value/Interest), supporting the initial construct reliability and aligning with recognized practices in culturally responsive STEM education research. While formal psychometric testing (e.g., Cronbach's alpha, factor analysis) was limited by sample size, findings indicated conceptual stability. The use of Collins' BSSI model as a framework ensured that the instrument was not only psychometrically aligned but also socially and contextually relevant to underrepresented student populations in STEM.

Survey Scoring & Analytical Approach

Survey items used ordinal response options with slightly different scale lengths across items. To enable comparison across items and constructs, each item was converted to a percent-of-maximum score (POMS) ranging from 0 to 100, where higher values indicate stronger self-

perceptions (e.g., greater perceived capability, belonging, awareness, or networking). Construct composites were computed as the average of their corresponding items (Table 2).
Because the 2023 and 2025 samples represent independent cohorts rather than matched individuals, and because the response distributions were ordinal and non-normally distributed, pre–post comparisons were examined using Mann–Whitney U tests, which are robust to nonparametric data and unequal group sizes [27]. This approach provides a distribution-free test of differences in medians without assuming interval-scale properties or homogeneity of variance. To complement the nonparametric significance tests, Hedges' g was calculated as a standardized measure of effect size, providing a bias-corrected estimate of the magnitude of the mean difference suitable for small-sample contexts [28]. This dual approach allows interpretation of both statistical and practical significance, aligning with the exploratory and developmental nature of the *HS IDEAS* program evaluation. Given the small sample size, p-values were interpreted cautiously and considered alongside effect sizes and theoretical alignment with the program's theory of change (see Limitations).

Program Assessment

Because the surveys did not include a student-level identifier, the results are not paired pre/post comparisons. In addition, the post group was mostly seniors, while the pre group was mostly freshmen and sophomores. As such, they were treated as two independent samples (entry cohort vs. exit cohort) to confirm pre-/post-cohort-level trends consistent with the program theory of change, not individual-level change.

Findings & Discussion

Overall, pre/post findings suggest the program is most strongly influencing outcomes related to STEM social capital and engagement with STEM professionals, reflected in increased networking behaviors and corroborated by students' descriptions of high-value experiences centered on NASA exposure, collaborative hands-on work, and immersive camp-based learning. These findings extend prior NASA MUREP work by demonstrating how sustained, hybrid engagement models contribute not only to awareness but to measurable gains in STEM social capital and identity development. Reflective identity outcomes show a promising upward trend that should be monitored with larger samples and, where possible, linked to participation records to examine which program components most consistently support representation and mentor match experiences.

Construct-level Results

At the construct level, the clearest pre/post pattern was an increase in Networking Behaviors, from pre to post, driven by a higher frequency of students discussing STEM majors and careers with people in STEM (Table 2). Students reported more frequent engagement with STEM professionals and conversations about STEM majors and careers at post relative to pre (M_{pre} = 40.00, M_{post} = 52.08; Δ = 12.08), representing a moderate-to-large effect ($g = 0.754$) and a statistically detectable shift ($p = .032$). Median scores also increased (pre median = 37.50; post median = 56.25). Awareness of NASA research was stable (M_{pre} = 48.75, M_{post} = 47.92; $g = -0.042$, $p = .814$).

Table 2. Construct-level Summary (0 to 100) (Pre, n=20; Post, n=12)

Construct	Pre mean (0-100)	Post mean (0-100)	Mean diff (post-pre)	Hedges g	Mann-Whitney p
Networking behaviors	40.0	52.08	12.08	0.754	0.0322
Reflective identity (representation and mentor match)	43.33	56.25	12.92	0.633	0.0695
Value and motivation (NASA and STEM)	65.56	62.96	-2.59	-0.101	0.5288
Awareness (NASA research)	48.75	47.92	-0.83	-0.042	0.8142
Belonging and comfort (NASA/STEM spaces) [Assimilation]	51.67	55.56	3.89	0.104	0.8247
Capability (college STEM)	70.0	69.44	-0.56	-0.018	0.8525
Overall composite	52.46	57.7	5.24	0.288	0.5723

Collins' STEM Identity Constructs

Reflective identity (representation and mentor match) increased from pre to post (Mpre = 43.33, Mpost = 56.25; $\Delta = 12.92$), with a moderate effect ($g = 0.633$) that approached conventional significance thresholds ($p = .070$) though not statistically detectable in this small sample, suggesting a promising trend that merits continued measurement with larger samples. **Capability** for college STEM, comparatively stable across timepoints, remained high and unchanged (Mpre = 70.00, Mpost = 69.44; $g = -0.018$, $p = .853$). **Belonging** (**Assimilation**) and comfort at NASA/STEM spaces showed a small positive change (Mpre = 51.67, Mpost = 55.56; $g = 0.104$, $p = .825$). **Value and motivation** remained high with minimal change (Mpre = 65.56, Mpost = 62.96; $g = -0.101$, $p = .529$). The overall composite increased modestly (Mpre = 52.46, Mpost = 57.70; $g = 0.288$, $p = .572$), indicating broad, positive directional movement with the strongest contributions coming from networking-related items.

Item-level Results

Item-level results (Appendix C) help explain the construct patterns. The largest and most reliable shift was in students' reported frequency of talking with someone in a STEM career about STEM majors and careers (Q4.4). Scores increased from Mpre = 41.25 to Mpost = 60.42 ($\Delta = 19.17$), with a large effect ($g = 0.883$) and statistical evidence of a distributional shift ($p = .026$). In categorical terms, the proportion reporting "Frequently" or "Always" increased from 15.0% (pre) to 41.6% (post), while "Rarely" decreased from 30.0% to 8.3%.

The companion networking item - working with someone from a STEM career (Q4.3) - showed a smaller increase (Mpre = 38.75, Mpost = 43.75; $g = 0.222$, $p = .418$). Notably, category patterns suggested a shift away from "Rarely" and toward "Occasionally" at post, consistent with increased exposure opportunities, but still leaving room to deepen authentic collaboration with STEM professionals.

- Meeting or working with STEM mentors of the same race (Q3.2): Mpre = 43.75, Mpost = 56.25 ($g = 0.472$, $p = .140$)
- Meeting or working with STEM mentors of the same gender (Q3.2.1): Mpre = 41.25, Mpost = 54.17 ($g = 0.472$, $p = .237$)
- Belief that shared identity can shape mentor-mentee expectations (Q3.9): Mpre = 45.00, Mpost = 58.33 ($g = 0.398$, $p = .272$)

Other items were stable across time points, including perceived capability to pursue a college STEM degree (Q3.8), belonging at NASA (Q3.3), and awareness of ongoing NASA research (Q4.6). The item assessing NASA mission importance for space travel (Q4.2) decreased modestly ($M_{pre} = 73.33$, $M_{post} = 61.11$; $g = -0.429$, $p = .141$), which may reflect calibration (a shift from "Completely" toward "Strongly") rather than a substantive drop in valuing NASA; this interpretation is supported by the qualitative data noting NASA exposure as highly valuable.

Qualitative Findings (Open-ended Responses)

Students' open-ended responses about the most valuable (Q5.1) and least valuable (Q5.2) experiences contextualized the quantitative patterns (Table 3). Thematic coding suggested that 2023 pre responses most commonly emphasized early-stage exposure experiences such as hands-on activities, school-based STEM clubs/classes, and a subset of students indicating they were not yet sure what was most valuable (consistent with entry timing). In contrast, 2025 post responses more consistently highlighted summer camp/residential experiences, hands-on projects and workshops, NASA exposure (site visits and SMEs), and peer connection and teamwork. This shift in perceived value aligns with the observed gains in networking behaviors, as many of the most-valued post experiences are interaction-rich contexts that naturally create opportunities for professional conversation, collaboration, and STEM identity reinforcement.

For the least valuable experiences, many students, especially at post, reported no clearly least valuable component, and the remaining responses tended to point to isolated issues such as fit/mismatch with a particular activity, expectation mismatch, or logistical/technical friction rather than dissatisfaction with core program elements. These results suggest that program refinements should prioritize smoothing implementation barriers while continuing to scale the high-impact components students consistently describe as meaningful (camps, hands-on builds, NASA exposure, and relationship-rich mentoring experiences).

Table 3. Most and Least Valuable Experiences: Theme Counts (Top Themes by Year)

	Most Valuable		**Least Valuable**	
Theme	2023	2025	2023	2025
Hands-on labs/workshops/projects	4	4	0	3
Mentoring/representation	1	0		
NASA exposure/site visit/SMEs	1	3	1	1
Peer connection/teamwork	1	3	1	0
School clubs/classes	4	0	1	0
Summer camp / residential	0	4	0	2
Uncertain/not yet	2	0	3	1

Mechanism-consistent Associations Among Constructs

To assess whether survey outcomes align with the logic model's pathways (e.g., identity/belonging/value supporting engagement and STEM social capital), we estimated partial Spearman correlations among construct composites while controlling for timepoint (2023 vs 2025). Constructs were scored on a 0–100 percent-of-maximum scale.

Table 4. Partial Spearman, ρ, correlations (controlling for timepoint).

Construct A	Construct B	n	Partial Spearman ρ	p
Reflective identity (representation and mentor match)	Networking behaviors	32	0.49	0.005
Belonging and comfort (NASA/STEM spaces)	Networking behaviors	32	0.53	0.002
Value and motivation (NASA and STEM)	Networking behaviors	32	0.61	<.001
Capability (college STEM)	Networking behaviors	32	0.63	<.001
Awareness (NASA research)	Networking behaviors	32	0.43	0.014
Belonging and comfort (NASA/STEM spaces)	Value and motivation (NASA and STEM)	32	0.66	<.001

Inter-construct associations were consistent with the FAMA logic model pathways linking students' identity-, belonging-, and value-related perceptions to engagement and STEM social capital. Belonging/comfort at NASA was positively associated with NASA/STEM value and motivation (partial Spearman $\rho = 0.66$, $p < .001$, $n = 32$). STEM college capability was positively associated with networking behaviors (partial Spearman $\rho = 0.63$, $p < .001$, $n = 32$). NASA/STEM value and motivation were positively associated with networking behaviors (partial Spearman $\rho = 0.61$, $p < .001$, $n = 32$). Belonging/comfort at NASA was positively associated with networking behaviors (partial Spearman $\rho = 0.53$, $p = 0.002$, $n = 32$). These relationships persisted after controlling for timepoint (pre vs post), providing mechanism-consistent evidence that students reporting stronger mentoring (psychosocial supports) also reported higher networking engagement with STEM professionals.

Implementation Reach Indicator Using Program Touchpoints

To connect implementation to near-term outputs in the logic model (e.g., increased awareness of NASA missions/resources [Q4.2]), we used Q42 participation checklist (program touchpoints) to test whether baseline outreach exposure was associated with higher NASA research awareness at baseline (2023 pre only). As an implementation-aligned test of early program reach, we examined whether students who reported receiving a school-based FAMA presentation at baseline also reported higher awareness of ongoing NASA research (a near-term logic model output). In the 2023 pre-sample, students who indicated a school presentation ($n = 5$) reported higher NASA research awareness ($M = 65.00$) than those who did not ($n = 15$, $M = 43.33$). This difference was detectable using a Mann–Whitney U test ($p = 0.038$) with a standardized difference of $g = 1.11$. This pattern provides preliminary support for the idea that early outreach may contribute to the logic model's short-term awareness outcomes.

Conclusion

FAMA has made a profound impact on both students and the community, creating opportunities for growth and learning that extend beyond the classroom. Through its ongoing partnerships with NASA, FAMA has expanded STEM programs not only locally but also on a broader scale, demonstrating the effectiveness of targeted STEM initiatives in marginalized communities [29].

By fostering curiosity, inclusion, and innovation, FAMA continues to shape the next generation of STEM leaders, a crucial effort to broaden participation and success in STEM, particularly among underrepresented populations [30]. FAMA encourages further research and development in both aerospace and environmental sciences, driving progress that will shape the future of these critical fields.

Implications of the Work and Future Directions

The outcomes of the FAMA program highlight the critical role of sustained, community-based partnerships in expanding equitable access to STEM learning opportunities. By collaborating with national organizations such as NASA and aligning programming with community needs, FAMA demonstrates how targeted STEM initiatives can serve as powerful mechanisms for addressing systemic inequities in education. These findings reinforce national calls to broaden participation in STEM by creating inclusive, culturally responsive, and grounded in authentic scientific practices [30]. The program's emphasis on experiential learning and family engagement also suggests that meaningful STEM identity development is not limited to classroom instruction but emerges through collective, community-driven experiences.

Future directions for FAMA include scaling the model to additional communities and deepening research on long-term student outcomes, particularly in postsecondary enrollment, persistence, and career trajectories in STEM fields. Further investigation is also warranted to examine how interdisciplinary connections between aerospace and environmental sciences can be leveraged to address pressing global challenges, including climate change, sustainability, and technological innovation. As emphasized by the Institute for Systems Biology [29], integrating research with education can strengthen both scientific advancement and workforce development. In this way, FAMA serves not only as a local intervention but as a scalable framework for advancing equity, innovation, and social impact within STEM education.

Limitations

These findings should be interpreted in light of several limitations. First, surveys were administered only at program entry (2023) and end-of-cycle (2025), with no mid-program (2024) or end-of-component data collection (e.g., after specific webinars, Saturday Deep Dives, site visits, Summer camps, etc.). As a result, planned analyses examining participation dosage as a mechanism for change could not be evaluated using within-student growth trajectories or temporally ordered exposure measures, and checklist-style reporting of attended events is susceptible to recall error. Second, the post-survey analytic sample was small, which limits statistical power, precision of estimates, and subgroup comparisons (e.g., by camp participation across years). Finally, the dataset does not include a stable student identifier that would allow matched pre/post analyses at the individual level; therefore, results reflect cohort-level pre/post patterns rather than person-level change.

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Appendices

Appendix A: Self-Perception Survey

FAMA 3: HS IDEAS Self-Perception Survey Questions

1. Which FAMA 3: HS IDEAS activities have you attended or completed so far? (Select all that apply.)

☐ FAMA 3 personnel visited my school for a presentation (December)
☐ FAMA 3 orientation at [UNIVERSITY Site] (January)
☐ NASA EPDC/FAMA 3 student digital badge(s)
☐ FAMA 3 webinar(s)
☐ FAMA 3 Citizen Researcher Saturday workshop(s)
☐ FAMA 3 summer camp (July)

2. To what extent do you feel capable of going to college for a STEM major?

Not at all	Slightly	Moderately	Strongly	Completely / Very strongly
○	○	○	○	○

3. To what extent would you want to work at NASA or another STEM-focused company?

None at all	A little	A moderate amount	A lot	A great deal
○	○	○	○	○

4. How often do you work with or meet STEM mentors or STEM teachers who are the same race as you?

Never	Sometimes	About half the time	Most of the time	Always
○	○	○	○	○

5. How often do you work with or meet STEM mentors or STEM teachers who are the same gender as you?

Never	Sometimes	About half the time	Most of the time	Always
○	○	○	○	○

6. To what extent do you feel you would belong and feel comfortable working at NASA?

Not at all	Somewhat	Moderately	Strongly	Fully / Extremely comfortable
○	○	○	○	○

7. To what extent has the FAMA 3: HS IDEAS program positively affected your perspective and goals toward pursuing a STEM degree or job?

None at all	A little	A moderate amount	A lot	A great deal
○	○	○	○	○

8. To what extent do you believe personal/professional differences may affect mentor–mentee performance?

Not at all	Slightly	Moderately	Strongly	Completely / Very strongly
○	○	○	○	○

9. To what extent is NASA's mission for space travel important to you?

Not at all	Slightly	Moderately	Strongly	Completely / Very strongly
○	○	○	○	○

10. How often do you talk about possible STEM majors or STEM careers with people who work in STEM fields?

Never	Rarely	Occasionally	Frequently	Always
○	○	○	○	○

11. How often do you work with someone from a STEM career?

Never	Rarely	Occasionally	Frequently	Always
○	○	○	○	○

12. To what extent are you aware of ongoing research performed by NASA?

Not at all	Slightly	Moderately	Strongly	Completely / Very strongly
○	○	○	○	○

Open-Ended Questions
13. Which HS IDEAS program experience(s) have been most valuable to you so far? Please explain.
14. Which HS IDEAS program experience(s) have been least valuable to you so far? Please explain.

Appendix B. Table 1. ***Participant Snapshot (Completed Surveys), by Timepoint***

Characteristic	Category	2023 Pre n (%)	2025 Post n (%)
	Completed surveys (N)	20	12
Gender	Boy/Man	8 (40.0%)	4 (33.3%)
	Girl/Woman	9 (45.0%)	7 (58.3%)
	Non-Binary	2 (10.0%)	0 (0.0%)
	Transgender	1 (5.0%)	0 (0.0%)
	Prefer not to answer	0 (0.0%)	1 (8.3%)
Hispanic/Latino(a) identity	Yes	12 (60.0%)	10 (83.3%)
	No	8 (40.0%)	2 (16.7%)
Race	American Indian or Alaska Native	0 (0.0%)	1 (8.3%)
	Asian	1 (5.0%)	0 (0.0%)
	Black or African American	2 (10.0%)	0 (0.0%)
	Native Hawaiian or Pacific Islander	1 (5.0%)	0 (0.0%)
	Other	2 (10.0%)	2 (16.7%)
	White	14 (70.0%)	9 (75.0%)
Grade classification	Freshman	9 (45.0%)	0 (0.0%)
	Sophomore	6 (30.0%)	1 (8.3%)
	Junior	5 (25.0%)	3 (25.0%)
	Senior	0 (0.0%)	8 (66.7%)

Note. Percentages are within timepoint (column percents). Race is single-choice as captured in the export.

Appendix C. Item-level Summary (Pre, n=20; Post, n=12)

QLTR Item Code	Item label (Survey #)	Pre mean (0-100)	Post mean (0-100)	Mean diff (post-pre)	Hedges g	Mann-Whitney p
Q4.4	**Networking**: talk about STEM majors/careers with someone in STEM career (S10)	41.25	60.42	19.17	0.883	0.0261
Q3.2	**Reflective identity**: meet/work with STEM mentors same race (S4)	43.75	56.25	12.5	0.472	0.1398
Q4.2	**Cultural value**: NASA mission importance for space travel (S9)	73.33	61.11	-12.22	-0.429	0.1413
Q3.2.1	**Reflective identity**: meet/work with STEM mentors same gender (S6)	41.25	54.17	12.92	0.472	0.2368
Q3.9	**Reflective identity belief**: shared identity affects mentor/mentee expectations (S8)	45.0	58.33	13.33	0.398	0.272
Q4.3	**Networking:** work with someone from a STEM career (S11)	38.75	43.75	5.0	0.222	0.4184
Q3.6	**Program impact (Value)**: affected dreams and goals toward STEM degree/job (S7)	60.0	66.67	6.67	0.191	0.7294
Q4.6	**Awareness**: aware of ongoing NASA research (S12)	48.75	47.92	-0.83	-0.042	0.8142
Q3.3	**Assimilation/ Belonging**: feel you would belong and be comfortable at NASA (S6)	51.67	55.56	3.89	0.104	0.8247
Q3.8	**Capability**: feel capable of going to college for STEM (S2)	70.0	69.44	-0.56	-0.018	0.8525
Q3.1	**Value/Motivation**: want to work at NASA or another STEM org (S3)	63.33	61.11	-2.22	-0.062	0.854

Appendix D. HS IDEAS Self-Perception Survey Construct Alignment and Validation Summary

Item Code	Prompt (Abbreviated)	Aligned Construct	Theoretical Source	Validation Type & Rationale
Q3.8	To what extent do you feel capable of going to college for STEM? (S2)	Competence / Ability	BSSI dimension: Self-efficacy and capability beliefs (Collins, 2018, pp.160–162)	Content validity—measures perceived STEM competence; aligned with Piaget's constructivism and BSSI competence dimension.
Q3.1	To what extent would you want to work at NASA or another STEM company? (S3)	Value / Motivation	BSSI dimension: STEM Value / Interest; Eccles' expectancy–value theory (cited in Collins, 2018, p.152)	Construct validity—assesses intrinsic motivation and aspirational alignment; expert review confirmed phrasing clarity.
Q3.2	How often do you meet STEM mentors or teachers of the same race? (S4)	Reflective Identity	BSSI dimension: Belonging through racial identity reflection (p.161)	Face validity—peer-reviewed by faculty to ensure representation relevance; supports reflection on social belonging.
Q3.2.1	How often do you meet STEM mentors or teachers of the same gender? (S5)	Reflective Identity	BSSI dimension: Gender-based identity in STEM (pp.161–162)	Content validity—assesses gender inclusion; reviewed by gender-in-STEM subject experts for clarity and sensitivity.
Q3.3	To what extent would you feel you belong or feel comfortable working at NASA? (S6)	Assimilation (Belonging)	BSSI dimension: STEM cultural fit and identity comfort (pp.160, 162)	Construct validity—maps to assimilation process in BSSI; field-tested for comprehension with pilot cohort.
Q3.6	To what extent has this HS IDEAS program affected your goals toward a STEM degree or job? (S7)	Value / Motivation	BSSI dimension: STEM Value / Interest (p.160)	Content validity—captures program influence on intrinsic motivation; aligned with constructivist engagement theory.
Q3.9	To what extent do you believe personal/professional differences may affect mentor–mentee performance? (S8)	Reflective Identity	BSSI dimension: Cultural interaction & belonging (p.161)	Face validity—validated through expert panel; measures perceived cross-cultural dynamics in mentorship.
Q4.2	To what extent is NASA's mission for space travel important to you? (S9)	Cultural Value / Awareness	Extension of BSSI Value / Interest within external environment (p.160)	Programmatic validity—custom item linking NASA theme to cultural alignment; reviewed by NASA Education Specialist/Liaison.
Q4.3	How often do you work with someone from a STEM career? (S10)	Networking (External Environment)	BSSI external context: School / Work / Career space (pp.160-161)	Construct validity—extends BSSI model; maps to "external environment" dimension.
Q4.4	How often do you talk about possible STEM majors or careers with people in the field? (S11)	Networking (External Environment)	BSSI: Reflective Identity and Belonging reinforcement (pp.160-161)	Reliability evidence—consistent responses across networking items; triangulated with mentor logs.
Q4.6	To what extent are you aware of ongoing NASA research? (S12)	STEM Awareness / Value Connection	BSSI Value / Interest extension (p.160); STEM identity as contextual awareness	Face & content validity—assesses real-world relevance and awareness; piloted for comprehension and scale consistency.

Validity: Face - relevant to participants; Content -representative inclusion; Construct - convergence to theoretical relationship