A National Evaluation of Non-Cognitive Outcomes and STEM Persistence Among Underrepresented Engineering Students (Research)

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Non-Cognitive Outcomes: Predicting STEM Identity and STEM Persistence for Underrepresented Engineering Students in Experiential Programs

Introduction

Research over the last two decades has highlighted non-cognitive factors as central drivers of persistence in engineering majors and careers, particularly for students who are historically underrepresented in STEM. Non-cognitive constructs such as self-efficacy, sense of belonging, and professional identity work alongside traditional academic preparation to shape whether students see themselves as legitimate members of the engineering community and remain committed to STEM pathways. Empirical studies show that authentic research and design experiences, targeted mentoring, and collaborative learning environments can significantly enhance these non-cognitive outcomes and, in turn, increase STEM commitment for both majority and underrepresented students.

These factors may be especially consequential for racially and ethnically underrepresented engineering students, who disproportionately encounter stereotype threat, isolation, and constrained access to high-quality mentoring and research opportunities. For these students, stronger self-efficacy, belonging, and professional identity can perhaps buffer against exclusionary experiences and support long-term persistence in engineering degrees and careers. Programs that provide authentic research and engineering design experiences, structured mentoring, and intentional community-building are therefore particularly important mechanisms for promoting non-cognitive outcomes and STEM persistence among underrepresented engineering students.

We were contracted to conduct a national evaluation of the NASA National Space Grant College and Fellowship Project (Space Grant). The Space Grant program is a nationwide network of 52 university-based program sites which include the 50 states, Washington DC, and Puerto Rico. The program funds research, education, and public engagement projects aligned with aeronautics and space priorities and provides fellowships, scholarships, and a wide range of authentic STEM experiences for undergraduates and graduate students. Examples of experiential learning opportunities include NASA internships (e.g., rover-related 3D modeling and mobility test bed testing, spacesuit life-support backpack design, and experiments on space applications), faculty-mentored research projects, and student competition teams participating in NASA challenges such as Lunabotics, CubeSats, and rocket design competitions. The overall purpose of the national evaluation was to measure the impact of the Space Grant program on post-secondary students' STEM identity.

This paper is a subset analysis of the national evaluation and specifically examines non-cognitive outcomes (self-efficacy, belonging, professional identity, and community of practice) and STEM persistence-related factors for engineering students, with a focus on racially/ethnically underrepresented engineering students who participated in experiential learning provided through NASA's Space Grant program.

Literature Review

A growing body of research [1] – [12] has identified non-cognitive constructs – specifically self-efficacy, sense of belonging, and professional identity – as central driver of persistence and success in STEM fields, alongside traditional academic preparation. Social-cognitive and identity-based frameworks emphasize that persistence in STEM extends beyond academic preparation and is deeply influenced by students' confidence in their abilities, their sense of inclusion within learning communities, and the extent to which they view themselves as legitimate members of the professional STEM community. Empirical studies have shown that authentic research experiences, targeted mentoring, and participation in collaborative learning environments can significantly enhance these non-cognitive outcomes, particularly for students from underrepresented backgrounds. Collectively, this body of work establishes the theoretical and empirical foundation for evaluating how experiential STEM programs foster self-efficacy, belonging, and identity development that contribute to long-term persistence and career commitment among engineering students. This paper is situated within this literature, extending prior work by examining these non-cognitive constructs in a large, nationally distributed sample of engineering students engaged in experiential learning, with an explicit focus on differential patterns for underrepresented engineering students participating in the nationwide program.

Non-cognitive Factors and STEM Persistence

Social-cognitive and identity-based models of persistence emphasize that students' decisions to remain in STEM are shaped not only by academic preparation but also by self-efficacy beliefs, perceived belonging, and developing professional identities [1] – [5]. Earlier studies [2], [3] have demonstrated that research experiences can enhance science/engineering self-efficacy and identity, which in turn predict increased commitment to STEM careers for both majority and underrepresented students. Subsequent work [4], [5] has reinforced that higher STEM self-efficacy is associated with better performance and longer persistence, and that gains in self-efficacy can be produced through mastery experiences, mentoring, and engagement in authentic research or design work.

Sense of belonging – feeling recognized, respected, and valued in one's academic community – has emerged as another important predictor of persistence, often especially salient for underrepresented students who contend with stereotype threat and isolation. Longitudinal studies [1], [6] show that STEM-specific belonging can be a stronger predictor of intentions to persist than more global measures of campus belonging, particularly in computing and engineering contexts. Interventions that foster inclusive climates, peer networks, and mentoring relationships have been shown to improve belonging and, in some cases, narrow equity gaps [1], [6], [4], [7] .

Professional identity, sometimes framed as “science” or “engineering” identity, captures the degree to which students see themselves as members of a professional STEM community. Higher professional identity has been linked to increased engagement, persistence, and pursuit of advanced STEM training, with particularly strong effects for students from historically underrepresented groups [2],[3], [8]. Studies suggests [2], [3], [8] that identity development in STEM is supported when students have recurring opportunities to perform the role of a professional (e.g., conducting research, presenting work), to receive recognition from mentors and peers, and to participate in communities of practice that normalize their presence in the field.

Experiential Learning and Communities of Practice

Course-based undergraduate research experiences (CUREs) [4], vertically integrated research projects [5], [9], and intensive research internships have consistently been associated with increased self-efficacy, identity, and STEM intentions for diverse student populations. These experiences tend to be most powerful when they combine authentic tasks (e.g., designing experiments, using professional equipment, presenting results) with strong mentoring and peer collaboration. For underrepresented students, access to high-quality mentoring and visible role models enhances belonging, validates their contributions, and supports identity development [3], [6].

Communities of practice – social structures in which novices and experts collaborate on meaningful work – provide a theoretical lens for understanding how experiential programs shape identity. It has been shown that participation in such communities offers students legitimate roles, shared goals, and opportunities for mutual engagement, which can translate into stronger STEM identities and more resilient persistence pathways [3], [8].

The results from the program evaluation build on this literature by examining these constructs in a large, nationwide sample of engineering students engaged in authentic aeronautics and space-related STEM experiences, with a particular emphasis on differential patterns for underrepresented engineering students.

Methodology

The national evaluation was reviewed and approved under an exempt protocol by the University of Alaska Fairbanks Institutional Review Board, and all procedures complied with institutional and federal guidelines for human subjects research, including informed consent for survey participation. The evaluation used an outcomes-based approach to examine short-term (post-only) and medium-term (pre-post) outcomes aligned with the program’s logic model.

Five overarching evaluation questions guided the study:

1. To what extent are Space Grant activities relevant to NASA’s STEM engagement goals and priorities (NASA Strategy for STEM 2020–2023)?

2. To what extent are short-term outcomes met (student satisfaction with their STEM experience, perceived authenticity, autonomy, and perceived gains in STEM content and skills needed for a future in STEM)?
3. To what extent are medium-term outcomes met (increased self-efficacy in STEM, feeling recognized as a contributing member of the STEM community, increased identity as someone who works in a NASA-related STEM field, and aspirations to persist in STEM)?
4. What is the relationship between constructs that promote STEM identity?
5. Are there differences between students underrepresented and represented in STEM in the Space Grant outcomes represented by the logic model?

The present paper addresses Questions 4 and 5 for the engineering subsample by examining how non-cognitive constructs (self-efficacy, belonging, professional identity, and community of practice) relate to STEM identity and career decidedness and whether these relationships differ for racially/ethnically underrepresented engineering students. The underrepresented group included students who self-identified themselves as Black, Hispanic/Latino, American Indian, Alaska Native, Pacific Islander alone or in combination with other races.

Instrument and Measures

The standardized survey, administered nationwide across the program, provided a structured framework for assessing program impact on student outcomes, particularly in relation to STEM identity, research engagement, and career-related aspirations. The survey instrument included 10 validated multi-item scales, plus single-item measures, each designed to measure different aspects of students' academic and professional development. Cronbach's alpha coefficients were used to indicate internal reliability of the survey items.

Four of the scales related to program best practices and six related to student outcomes. In addition, we also measured students' satisfaction with relationships, meaningful work, and overall program experience. This paper focuses on scales and survey items relevant to self-efficacy, belonging, profession identity, community of practice, and overall experience satisfaction.

Measures related to program best practices

- Authenticity Scale (12 items; $\alpha = .84$): Post-only scale assessing frequency of engaging in practices characteristic of STEM professionals (e.g., data analysis, design, testing, presenting).
- Mentoring Best Practices Scale (9 items; $\alpha = .95$): Post-only scale measuring perceived quality of mentoring (e.g., accessibility, support, modeling of scientific/engineering processes, career guidance).
- Community of Practice Scale (5 items; $\alpha = .85$): Post-only scale measuring perceptions of collaboration, networking, and shared learning with peers, faculty, and

professionals – the extent to which students' STEM experiences included practices that foster student belonging [10].

- Content Knowledge and Skills Scale (4 items; $\alpha = .82$): Post-only scale capturing perceived gains in content knowledge and research/design skills relevant to future STEM work.

Measures related to student outcomes

- Belonging Scale (12 items; $\alpha = .91$): Adapted from the University of Colorado Campus and Workplace Culture Survey [7], measuring feelings of inclusion, respect, and support within STEM departments (pre and post).
- Academic Self-Efficacy Scale (6 items; $\alpha = .94$): Adapted from Bong's Self-Efficacy for Academic Achievement Scale [11], assessing confidence in mastering course content and performing well in STEM coursework (pre and post).

- Career Decidedness and STEM Aspirations Scale (4 items; $\alpha = .84$): Pre-post items assessing clarity of career plans and intention to pursue STEM degrees and careers.

- STEM Practices Self-Efficacy Scale (11 items; $\alpha = .93$): Adapted from Estrada et al. and Chemers et al. [2],[3], capturing confidence in performing research and engineering design tasks (pre and post).

- STEM Identity Scale (6 items; $\alpha = .89$): Adapted from Estrada et al. and Chemers et al. [2],[3], assessing perceptions of oneself as someone who works in a STEM field (pre and post).

- Professional Identity Overlap: Adopted from McDonald et al., a single-item visual measure of perceived overlap between self and a STEM professional [12] (Figure 1).

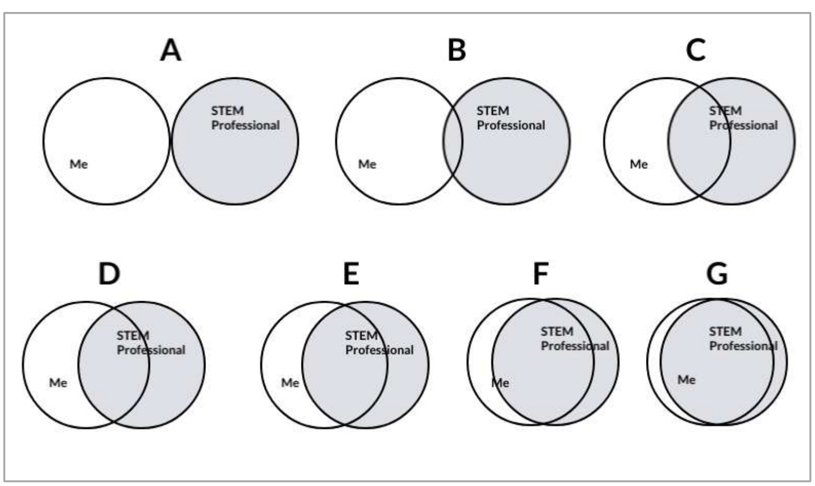

Figure 1. Single-item measure for assessing self-perception as a STEM professional [12].

Sample

There were a total of 1,510 program students and 247 non-program comparison students who completed matched pre-post surveys, representing all 50 states, Wahington DC, and Puerto Rico. Approximately half of the program participants identified as female (49.3%), compared with 57.9% of comparison students. About 25.8% of all respondents identified as racially/ethnically underrepresented in STEM – students who identified as Black, Hispanic/Latino, American Indian, Alaska Native, or Pacific Islander alone or in combination with other races – with similar proportions in program and comparison groups.

Sample. The engineering student sample for this paper was drawn from the larger pool of 1,510 program participants with matched pre-post surveys, of whom 1,486 provided complete information on major and race/ethnicity. Among these, 685 students reported an engineering major or primary focus and 801 reported a non-engineering STEM focus; the distribution of underrepresented and represented students did not differ significantly between engineering and other STEM fields. Within the engineering subsample, 24% (n = 162) identified with racial/ethnic groups typically underrepresented in STEM (e.g., Black, Hispanic/Latino, American Indian/Alaska Native, Native Hawaiian/Pacific Islander, alone or in combination), while 76% (n = 523) identified with groups typically represented in STEM (White, non-Latino or Asian).

Sample Demographics. Demographic comparisons revealed substantial differences between underrepresented and represented engineering students across most characteristics except gender (Table 1). Both groups were majority male, and the proportion of women was similar (40.3% among underrepresented students vs. 37.5% among represented students), with no statistically significant difference. However, underrepresented engineering students were significantly more likely to be first-generation college students (38.4% vs. 10.7%), more likely to report experiencing financial hardship “most of the time” or “almost always” (44.3% vs. 19.1%), more likely to attend community colleges (11.1% vs. 2.3%), and less likely to have a parent or guardian working in a STEM field (25.3% vs. 51.1%). While the majority of both groups were pursuing bachelor’s degrees (approximately 79%), underrepresented students were more likely to be enrolled in associate’s programs and less likely to be enrolled in graduate programs than their represented peers.

Table 1. Proportion of demographic responses by representation status among engineering students.

Engineering Students	Underrepresented Students		Represented Students	
	n	Percent	n	Percent
Gender	159		522	
Female		40.3%		37.5%
Male		57.2%		61.1%
Other		2.5%		1.3%
Degree Program*	162		523	
Associate's		7.4%		1.0%
Bachelor's		79.0%		78.6%
Graduate degree		13.6%		20.5%
First generation college student*	159		512	
Yes		38.4%		10.7%
No		61.6%		89.3%
Parents work in STEM*	157		506	
Yes		25.3%		51.1%
No		71.6%		45.7%
Experienced financial hardship most of the time or almost always*	160		509	
Yes		44.3%		19.1%
No		55.7%		80.9%
Type of institution*				
Community College	162	11.1%	523	2.3%

* $p < .050$ on a chi-square analysis

The engineering sample was geographically and institutionally diverse. The 685 engineering students were enrolled at 222 different institutions, with underrepresented engineering students attending 97 institutions and represented students attending 180 institutions. Nearly all engineering students were enrolled at predominantly White institutions; fewer than 5% of underrepresented engineering students (n = 8) attended minority-serving institutions, all at four historically Black colleges and universities, and no engineering students in the sample attended women's colleges or Tribal colleges. Engineering students were located in 51 of the 52 program sites (the 50 states, Washington DC, and Puerto Rico), with no engineering respondents from Rhode Island. Represented engineering students were present in all but Puerto Rico, while underrepresented engineering students were spread across 39 of the 52 program sites. Underrepresented students were not represented in Georgia, Kansas, Kentucky, Maine, Mississippi, North Carolina, North Dakota, New Hampshire, Oklahoma, South Carolina, Tennessee, and Wyoming. As discussed in the Limitations section, this gap in representation does not indicate that underrepresented engineering students were absent from programs in these states; rather, they reflect constraints in our sampling frame and differential response rates. We relied on each program site to provide contact information for students who had participated in funded opportunities, and not all sites supplied complete student lists or achieved strong survey response rates among underrepresented students.

Data Collection and Analysis

We collected data through student surveys. Across six survey rounds (February 2023-August 2024), a total of 1,510 students completed a matched pre- and post-survey, a 30.6% response rate. Surveys were distributed to post-secondary program and non-program (comparison) students. Program sites provided contact lists for program participants at six time points; all identified students received email invitations to complete pre and post surveys, with $25 gift card incentives. Comparison students were recruited via flyers and social media, with a .edu email requirement added to address bot responses and scammers.

Survey data were analyzed in R using descriptive statistics, chi-square tests, one-way ANOVAs, paired t-tests, two-way ANOVAs, ANCOVA, and multiple linear regression. Pre-post analyses used paired t-tests to examine within-group changes and ANCOVA to compare gains between engineering and non-engineering majors and between underrepresented and represented engineering students, adjusting for baseline scores.

Each scale measure used a six-point scale with a "1" being a very low-level, and a "6" being a very high level. Further interpretation of the scale is outlined in Table 2. We used an equal interval method to divide the data range into equal-sized subranges based on the minimum and maximum values, ensuring that each class has the same numerical width regardless of how many data points fall into each class. Regression models estimated the contributions of non-cognitive variables and program characteristics to post-program STEM identity, separately for all engineering students and for underrepresented engineering students.

Table 2 Survey scale values

Scale Value	Scale interpretation
1.00-2.67	Low score
2.68-4.33	Moderate score
4.34-6.00	High score

Results

Overall, the results indicate that for the full engineering sample, professional identity is the strongest predictor of both post-program STEM identity and career decidedness, with additional contributions from academic self-efficacy, STEM practices self-efficacy, belonging, community of practice, autonomy, and program satisfaction. For underrepresented engineering students, program satisfaction, followed by academic self-efficacy, professional identity, and STEM practices self-efficacy, emerges as especially salient in predicting STEM identity and career decidedness. Content knowledge and skills gains demonstrate a suppression effect in the STEM identity model, suggesting that learning outcomes are most impactful when embedded in affirming, high-quality experiences. In the sections that follow, we detail these patterns for the full engineering sample and for underrepresented engineering students.

Non-Cognitive Outcomes

Across the non-cognitive measures, engineering students entered the program with relatively high scores and, in several areas, showed meaningful gains over time. **STEM practices self-efficacy** increased significantly from pre (M = 4.44) to post (M = 4.57) for engineering students, and engineering participants showed greater gains than non-engineering students; underrepresented engineering students started lower but closed the initial gap with represented peers by the end of the program. **Academic self-efficacy** was very high at baseline and remained stable (pre M = 5.31; post M = 5.30), and engineering students' perceptions of themselves as **STEM professionals** (pre M = 5.02; post M = 5.03) and their **career aspirations** were similarly high and unchanged over time for both engineering and non-engineering students.

Patterns for belonging and post-only outcomes highlight the program's role in addressing initial disparities for underrepresented engineering students. **Sense of belonging** in STEM was high at pre and slightly higher at post for all students, with small, non-significant increases; underrepresented engineering students began with lower belonging than represented students but reported comparable belonging by the end of the program. Post-survey measures showed that 42.5% of engineering students reported frequently or very frequently engaging in **authentic STEM practices**, with high frequencies for tasks such as data analysis (72.8%), use of laboratory techniques (58.8%), and use of laboratory equipment (57.2%); average authenticity scores were similar for underrepresented (M = 3.97) and represented engineering students (M = 4.03).

Most engineering students agreed that the program provided a strong **community of practice**, with underrepresented students reporting higher average scores (M = 5.00) than represented students (M = 4.82). Overall, 78% of engineering students were **satisfied or extremely satisfied with their experience** (engineering M = 4.69 vs. non-engineering M = 4.87), and engineering students reported high perceived **content gains**; with underrepresented engineering students reporting slightly higher average content gains (M = 4.75) than represented engineers (M = 4.67).

Predictors of STEM Identity and Career Decidedness for Engineering Students

A model examining predictors of post-program STEM identity and career decidedness for the program engineering students included community of practice, mentoring best practices, program satisfaction, STEM practices self-efficacy (post), academic self-efficacy (post), sense of belonging (post), professional identity (post), total amount of program funding awarded, total number of program awards/opportunities, autonomy (post), and content gains (post). In this section, we first summarize overall patterns in predictors of STEM identity and career decidedness for engineering students. In the subsections that follow, we present detailed models for factors that promote STEM identity and factors that promote career decidedness for both the full engineering sample and for underrepresented engineering students.

Across regression models, results suggest that self-perception as a STEM professional and academic self-efficacy are significant predictors of engineering students' pursuit and persistence in STEM careers, including among students from underrepresented racial and ethnic groups. Non-cognitive factors associated with engagement in the STEM community – such as participation in a community of practice and a sense of belonging – were significant contributors to STEM identity among engineering students but did not emerge as significant for underrepresented students. Perceptions of program experiences were strongly associated with both STEM identity and career decidedness across the overall sample; however, these perceptions did not significantly influence career decidedness among underrepresented students. Lastly, confidence in STEM-specific skills was a significant predictor of career decidedness for engineering students, with particularly strong effects observed for those from underrepresented populations.

Predictors of STEM Identity

We first estimated a model including all program engineering students and then estimated a parallel model for racially/ethnically underrepresented engineering students.

All Engineering Students. A multiple regression analysis indicated that the model was statistically significant for represented engineering students ($F(11, 670) = 52.600$, $p < .001$), explaining 45.5% of the variance in post-program STEM identity. Five variables emerged as significant predictors of STEM identity:

- Professional identity ($\beta = 0.225$, $p < .001$)
- Academic self-efficacy ($\beta = 0.188$, $p < .001$)
- Sense of belonging ($\beta = 0.181$, $p < .001$)
- Community of practice ($\beta = 0.126$, $p < .001$)
- Program satisfaction ($\beta = 0.077$, $p = .019$)

Underrepresented Engineering Students. For underrepresented engineering students, a parallel regression model was also statistically significant ($F(11, 150) = 14.86$, $p < .001$), explaining 52.2% of the variance in STEM identity. Four variables emerged as significant predictors of STEM identity:

- Program satisfaction ($\beta = 0.227$, $p < .001$)
- Academic self-efficacy ($\beta = 0.212$, $p = .010$)
- Professional identity ($\beta = 0.184$, $p < .001$)
- Content gains ($\beta = -0.169$, $p = .011$)

Predictors of Career Decidedness

We then examined predictors of career decidedness, again estimating separate models for the full engineering sample and for underrepresented engineering students.

All Engineering Students. Consistent with the STEM identity model, identity as a STEM professional was the strongest predictor of career decidedness, followed by students' confidence in their STEM skills, overall satisfaction with their program experience, academic self-efficacy, and perceived autonomy in their roles. All other variables in the model were not significant predictors of career decidedness (all $p>.05$).

A multiple regression analysis indicated that the model was statistically significant, $F(11, 670) = 15.980$, $p < .001$, explaining a moderate portion of the variance in career decidedness ($R^2 = 0.208$). Five variables emerged as significant predictors of career decidedness:

- Professional identity ($\beta = 0.212$, $p < .001$)
- STEM practices self-efficacy ($\beta = 0.140$, $p = .001$)
- Program satisfaction ($\beta = 0.130$, $p = .004$)
- Academic self-efficacy ($\beta = 0.093$, $p = .021$)
- Sense of autonomy ($\beta = 0.084$ $p = .018$)

Underrepresented Engineering Students. As in the full engineering sample, underrepresented students with stronger identification as STEM professionals and higher confidence in their STEM practices and academic abilities reported higher levels of career decidedness. Notably, STEM practices self-efficacy and academic self-efficacy were relatively stronger predictors in the underrepresented student model than in the full-sample model of engineering students. All other factors in the model were not significant predictors of career decidedness (all $p > .05$).

A multiple regression analysis indicated that the parallel model for underrepresented engineering students was also statistically significant, $F(11, 150) = 6.180$, $p < .001$, explaining a moderate portion of the variance in STEM identity ($R^2 = 0.261$). Three variables emerged as significant predictors of career decidedness:

- Professional identity ($\beta = 0.210$, $p = .006$)
- STEM practices self-efficacy ($\beta = 0.204$, $p = .026$)
- Academic self-efficacy ($\beta = 0.201$, $p = .016$)

Limitations

This paper has several limitations that should be considered when interpreting the results. First, the analysis relies on students' self-reported aspirations and non-cognitive outcomes rather than verified academic or career trajectories, so it is not possible to determine whether observed gains in self-efficacy, identity, or decidedness translate into long-term persistence or STEM employment. Second, the engineering sample was not randomly drawn from all program participants or from the broader engineering student population because we depended on individual program sites to identify and share contact information for students who had participated in funded experiential opportunities. Program directors at each site were asked to provide names and emails for eligible students and then we distributed the survey invitation, but some sites did not provide complete awardee lists or had low response rates among the students who received survey invitations. As a result, the engineering sample reflects students who were both identified by their program and chose to complete the survey, rather than a probabilistic or fully representative national sample. This reliance on program-generated contact lists likely contributed to uneven coverage across program sites and helps explain why underrepresented engineering students were not represented in our sample from certain states (e.g., Georgia, North Carolina, New Hampshire), despite the presence of large engineering institutions in those locations. Consequently, the results should be interpreted as indicative of patterns among participating engineering students within the nationwide program rather than as estimates that generalize to all engineering students or even to all program-funded engineering participants. Third, the nationwide program is implemented heterogeneously across the country, and the survey did not fully capture variation in program structure, duration, or local context, constraining inferences about which specific design features drive the observed non-cognitive outcomes for engineering and underrepresented engineering students. Finally, because the underrepresented engineering subsample is relatively small, estimates for this group have reduced statistical power and may be unstable, so non-significant associations – particularly for belonging and community of practice – should be interpreted as inconclusive rather than definitively null, and future work with larger, more targeted samples is needed to confirm or refine these patterns.

Discussion

The results from this national evaluation underscore the central role of non-cognitive factors – academic self-efficacy, sense of belonging, STEM professional identity, and STEM practices self-efficacy – in shaping STEM identity and career trajectories for engineering students, particularly those typically underrepresented in the field. At a broad level, STEM professional identity emerged as the most powerful predictor of both STEM identity and career decidedness for the full engineering sample, highlighting that "seeing oneself" as a STEM professional is foundational for students' long-term engagement in STEM majors and careers. For underrepresented engineering students, this identity is intertwined not only with self-efficacy constructs but also with how they experience the program itself, pointing to the importance of high-quality, affirming learning environments for those navigating structural and social barriers. Overall, the results reinforce prior work showing that self-efficacy, belonging, and professional identity are central psychological mechanisms linking experiential programs to STEM identity and persistence.

STEM Identity and Non-cognitive Factors

Across all program engineering students, professional identity, academic self-efficacy, sense of belonging, community of practice, and program satisfaction were significant predictors of post-program STEM identity, together explaining nearly half of the variance in identity outcomes. Professional identity was the strongest predictor, indicating that students who internalize the role of "STEM professional" are most likely to report a strong STEM identity. The strong role of professional identity in predicting STEM identity and career decidedness aligns with prior work showing that science and engineering identity are critical mechanisms linking experiential programs to persistence, particularly for underrepresented students [2], [3], [8].

Academic self-efficacy and belonging also contributed substantially, suggesting that feeling academically capable and feeling included and respected within STEM environments are critical psychological resources for sustaining STEM identity. Community of practice further supported identity, implying that participation in collaborative networks and shared projects with mentors and peers helps students see themselves as legitimate members of the STEM community. Although a weaker predictor than the other constructs, program satisfaction still played a meaningful role, indicating that students' overall appraisal of their experience – whether they found it meaningful, supportive, and worthwhile – adds incremental value to identity development in STEM. Our results also highlight the importance of belonging and communities of practice for engineering students more broadly, echoing evidence that STEM-specific belonging often outperforms general campus belonging in predicting persistence and that inclusive peer and mentoring networks can help narrow equity gaps [1], [6], [10].

For underrepresented engineering students, the pattern of predictors shifted in telling ways. Program satisfaction was the strongest predictor of STEM identity in this subgroup, followed by academic self-efficacy and professional identity. The prominence of overall program satisfaction for underrepresented engineering students suggests that affirming, high-quality experiences remain a crucial lever for broadening participation, supporting calls for identity-affirming environments that normalize underrepresented students' presence in STEM [3], [8]. This suggests that the quality and impact of their most recent program experience – how supported, valued, and intellectually engaged they felt – are especially important for whether they come to see themselves as "STEM people." Academic self-efficacy remained a substantial predictor, underscoring that confidence in meeting academic demands is a key element of identity development. Professional identity also contributed significantly, indicating that underrepresented students benefit when they can concretely envision themselves in STEM roles. Notably, community of practice and belonging were not significant predictors of STEM identity for underrepresented engineering students in the analysis model, even though they were significant for the full engineering sample. Although community of practice and belonging did not emerge as significant predictors of STEM identity for underrepresented engineering students in the multivariate model, as stated in the limitations section, these findings should be interpreted cautiously. Statistically, these constructs likely share variance with program satisfaction and professional identity, which can lessen their unique effects in a relatively small subsample. Practically, once underrepresented engineering students achieve a baseline sense of belonging and community, the key differentiator for identity development may be the perceived quality and impact of their experiences, rather than incremental increases in belonging per se.

Additionally, the negative regression coefficient for content gains, despite a positive bivariate relationship with STEM identity, points to a suppression effect: content gains seem to support identity mainly through their overlap with satisfaction, self-efficacy, and professional identity. This pattern suggests that simply learning more content is not sufficient to build a strong STEM identity for underrepresented students; content learning matters most when it is embedded in experiences that also build confidence, recognition, and positive views of the program. Taken together, these findings imply that for underrepresented engineering students, STEM identity depends not only on what they know, but also on how they are treated, how capable they feel, and how clearly they can see themselves in the field.

Career Decidedness and Non-cognitive Factors

The predictors of career decidedness mirror many of the patterns observed for STEM identity, reinforcing the idea that identity and persistence intentions are tightly coupled. For the overall engineering sample, professional identity again emerged as the strongest predictor of career decidedness, followed by STEM practices self-efficacy, program satisfaction, academic self-efficacy, and autonomy. Students who more strongly identified as STEM professionals were more likely to report clear, committed plans for their future STEM careers or further education, suggesting that identity serves as a psychological bridge between present experiences and future pathways.

STEM practices self-efficacy – confidence in one's ability to perform research and engineering tasks – played a particularly important role in career decidedness, highlighting that feeling competent in the day-to-day practices of STEM (e.g., using tools, analyzing data, designing solutions) helps students commit to STEM futures. Program satisfaction and academic self-efficacy also shaped career decidedness, suggesting that students' global appraisal of their experiences and their belief in their academic capabilities reinforce their willingness to choose and stay with STEM career paths. Autonomy, although a more modest predictor, indicates that opportunities to make decisions, take ownership of projects, and shape their own learning contribute meaningfully to students' clarity and confidence about their careers.

For underrepresented engineering students, professional identity, STEM practices self-efficacy, and academic self-efficacy were the significant predictors of career decidedness. This pattern emphasizes that for these students, non-cognitive resources are especially critical in translating experience into firm career plans. Professional identity remained central, but the relative strength of STEM practices self-efficacy and academic self-efficacy increased in the underrepresented subgroup compared with the full sample. In other words, for underrepresented students, being confident in both their academic performance and their applied STEM skills is particularly important for deciding to pursue and persist in STEM careers. Consistent with social-cognitive models, higher academic and STEM practices self-efficacy were associated with stronger STEM identity and more decisive STEM career plans, reinforcing findings that experiential experiences and mentoring can produce gains in self-efficacy that translate into persistence [2], [4], [5]. These findings highlight that building strong skill-based and academic confidence may be especially impactful for underrepresented students who have often received mixed signals about their belonging and potential in engineering fields.

Implications for Practice

The collective pattern of results has several implications for the design of programs aimed at broadening participation and improving persistence among underrepresented engineering students. First, identity-focused strategies should be central, not peripheral. Programs should provide structured opportunities for students to enact the roles of engineers and STEM professionals (e.g., leading design tasks, presenting results to authentic audiences, mentoring peers), and they should explicitly recognize students' contributions as professional-caliber work. Such practices directly reinforce professional identity and, by extension, both STEM identity and career decidedness.

Second, interventions should intentionally build both academic and STEM practices self-efficacy. This involves more than exposure to challenging tasks; it requires scaffolded experiences, timely feedback, and explicit reflection on skill development so that students can connect their efforts and improvements to their growing competence. For underrepresented students, who may come in with lower initial confidence due to prior experiences, reducing gaps in self-efficacy for STEM practices and academics is especially important for supporting both identity and career commitment.

Third, belonging and community of practice remain critical, particularly for the larger engineering population, and likely still matter for underrepresented students even though they do not appear as independent predictors in multivariate models. Designing cohort-based experiences, peer learning communities, and cross-level mentoring structures can reinforce underrepresented students baseline feelings of being part of a broader STEM network that validates their presence and potential.

Finally, for underrepresented students in particular, program satisfaction played a big role in shaping STEM identity. This suggests that the overall environment, relational quality, and perceived fairness and responsiveness of the program (i.e., how well the engineering program adapts to and serves the specific needs, experiences, and goals of its students, rather than expecting all students to fit a fixed, one-size-fits-all model) are not "soft" extras but core drivers of STEM identity and, indirectly, persistence. Programs seeking to broaden participation should consider investing in practices that make experiences more meaningful, supportive, and responsive – such as providing authentic learning opportunities, structured mentor interaction, clear and ongoing communication, and avenues for student voice and feedback.

Conclusion

The results from the Space Grant program evaluation demonstrates that non-cognitive factors are not merely ancillary outcomes but central mechanisms through which experiential engineering programs and experiences influence underrepresented students’ STEM trajectories. Among the nationwide program’s engineering students, STEM professional identity, academic self-efficacy, sense of belonging, community of practice, program satisfaction, STEM practices self-efficacy, and autonomy jointly shape both how students see themselves in relation to STEM and how decisively they commit to STEM majors and careers. For racially and ethnically underrepresented engineering students, program satisfaction, academic self-efficacy, professional identity, and STEM practices self-efficacy are especially salient, underscoring that high-quality, affirming experiences and strong non-cognitive supports can help counteract inequities in both academic and career preparation and attainment.

By centering identity development, building strong academic and practices self-efficacy, fostering belonging and communities of practice, and ensuring that underrepresented students have high-quality, satisfying program experiences, engineering educators and program designers can meaningfully enhance both STEM identity and career decidedness. In doing so, they not only support individual students’ aspirations but also contribute to a more diverse, robust, and innovative STEM workforce.

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