The Influence of Experiential Learning on Undergraduate Students' STEM Identity and Career Intentions

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Abstract

Despite sustained efforts to increase the STEM workforce, many undergraduates leave STEM pathways before entering the workforce, particularly women and underrepresented students. Experiential learning that encompasses authentic STEM practices, effective mentoring, student autonomy, and student participation in a community of practice has emerged as a promising way to build the psychosocial foundations of STEM persistence, including STEM self-efficacy, academic self-efficacy, sense of belonging, and STEM identity. We examined how these experiential learning features operated within a national STEM program to encourage undergraduate students' STEM identity and career intentions. Using experiential learning and STEM identity frameworks, we developed a conceptual model in which four experiential features, authentic STEM experiences, effective mentoring, student autonomy, and participation in a community of practice, predict three psychosocial mediators: STEM self-efficacy, academic self-efficacy, and STEM belonging. Through a national evaluation of 52 statewide consortia representing a broad range of institution types including public and private universities, community colleges, HBCUs, TCUs, and industry partners, including the Commonwealth of Puerto Rico and Washington, D.C., we collected 1,119 matched pre- and post-surveys from undergraduate students and used structural equation modeling to test our model. The model demonstrated acceptable fit (CFI = 0.949, RMSEA = 0.074, SRMR = 0.026). Both pre-program beliefs and program features predicted post-program self-efficacy and belonging, which in turn strongly predicted STEM identity ($R^2 = 0.594$). STEM identity then predicted students' post-program career intentions ($R^2 = 0.358$). Our results highlight the important roles that authentic practice, community of practice, and effective mentoring play in supporting students' STEM self-efficacy, belonging, and identity at scale. Our findings also suggest that experiential programs should be intentionally structured as mentoring-rich, autonomy-supportive communities where students regularly share their work and are recognized as contributors.

I. Introduction

Despite sustained efforts to increase the STEM workforce, particularly among women and underrepresented groups, many undergraduates still leave STEM pathways before entering the workforce [1, 2, 3, 4]. Increasingly, experiential learning is being integrated into undergraduate STEM education [5, 6] and has promise to increase the number of students who graduate with a STEM degree and pursue a STEM career. Kolb [7] describes experiential learning as a cyclical process in which students engage in concrete experiences, reflect on them, develop more abstract understandings, and then test those understandings through new action. In STEM disciplines, undergraduate experiential learning often takes the form of research experiences, internships, and design challenges. When well-designed, these experiences provide not only hands-on tasks but also opportunities for students to exercise autonomy over their work, receive mentoring from experienced researchers and industry professionals, participate in a community of practice (a network of peers, mentors, and professionals who collaborate and support one another's academic and career goals [8]), and share their work with others.

Studies consistently show that students who participate in these types of well-designed experiences demonstrate higher STEM self-efficacy (confidence in their ability to successfully engage in STEM research and design activities [9, 10]), greater academic self-efficacy (perceived capability to master STEM coursework content [10]), a stronger sense of belonging to a STEM community [11, 12], and a clearer sense of themselves as STEM people [13], and are more likely to pursue a STEM career [14]. These relationships are grounded in a well-established body of evidence. Bandura's [9] self-efficacy theory identifies mastery experiences, the direct experience of successfully completing meaningful tasks, as the most powerful source of efficacy beliefs, suggesting that authentic STEM work is a particularly potent driver of self-efficacy development. Consistent with this, the National Academies of Sciences, Engineering, and Medicine [8] found that well-designed undergraduate research experiences reliably build students' STEM self-efficacy and sense of disciplinary belonging. Prior research also demonstrates that structured STEM programs that provide mentoring, peer interaction, and opportunities for recognition strengthen students' sense of belonging [11, 12] and clarify their career intentions [14]. These psychosocial outcomes are further grounded in Kolb's [7] Experiential Learning Theory, which describes how authentic tasks, mentoring relationships, and opportunities for student decision-making activate a cyclical process of experience, reflection, and growth.

Although the literature strongly illustrates convergence between experiential practices and positive STEM psychosocial outcomes, important gaps remain in understanding how specific aspects of experiential learning jointly shape students' STEM self-efficacy, academic self-efficacy, sense of belonging, and STEM identity, particularly in large, multi-institutional initiatives. Much of the existing literature examines only one or two mediating effects at a time [11, 12] or focuses on a single course [15], program, or institution [13, 16].

Our study addresses these gaps by examining a federally funded initiative operating through 52 statewide consortia across the United States, including the Commonwealth of Puerto Rico and Washington, D.C. The program provides undergraduate students with experiential learning opportunities including funded research experiences, industry and federal agency internships, and supported student competitions across a broad range of affiliates including public and private universities, community colleges, Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), women's colleges, government agencies, and industry partners. The program frequently funds students' experiential experiences through stipends or paid positions to reduce the need for outside employment, which may shape how students engage in experiential learning. Within this setting, we tested an integrated model linking four experiential learning features (authentic STEM practices, effective mentoring, student autonomy, and community of practice) to three psychosocial mediators (STEM self-efficacy, academic self-efficacy, and STEM belonging) and in turn to STEM identity and career intentions, using pre- and post-survey data from 1,119 undergraduate students. Our study addressed the following research questions: 1) Which experiential learning features most strongly predict post-program STEM self-efficacy, academic self-efficacy, and belonging? 2) How do these psychosocial constructs, together with pre-program beliefs, relate to students' post-program STEM identity and career intentions?

II. Methodology

We developed a conceptual model that integrates experiential learning best practices with key psychosocial mediators of STEM outcomes. The model incorporates four core experiential features: student engagement in authentic STEM practices (e.g., research and design, data collection and analysis), effective mentoring, autonomy in project work, and participation in a community of practice. It also incorporates three mediating psychosocial factors: STEM self-efficacy, academic self-efficacy, and sense of belonging in STEM. Although financial support is not treated as a "best practice" in our framework, we include funding amount as a contextual program feature. Together, these constructs form a comprehensive framework, as shown in Fig. 1, that we used to investigate the factors that shape students' STEM identity and, in turn, their intentions to pursue a STEM career.

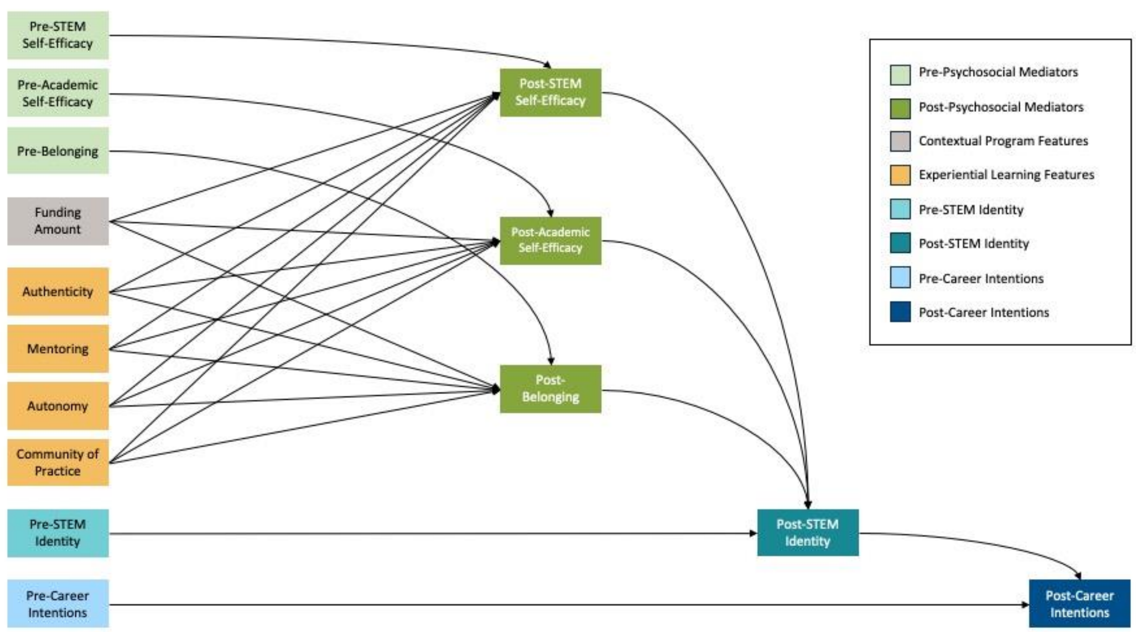

Fig. 1. Hypothesized path model of pre- and post-STEM perceptions, identity, and career intentions.

A. Study Context and Design

This study used a quantitative design to explore the factors influencing undergraduate students' intentions to pursue a career in a STEM field. We conducted the study within a national evaluation of 52 statewide consortia, including the Commonwealth of Puerto Rico and Washington, D.C. While the program serves both undergraduate (including community college) and graduate students, during the two-year evaluation period, the consortia awarded 81.7% of funding to undergraduate students.

Within this context, the program provides undergraduate students with experiential learning opportunities during the academic year and summer through three primary types of experiences:

research experiences, in which students work alongside faculty and graduate students on research projects, internships with industry partners or federal agencies, and student competitions. Many consortia also host research symposia and offer travel awards for students to present their work. All experiences are connected to broader scientific and technological priorities. Students across a range of STEM disciplines participate in these opportunities for a minimum of one semester, including summer terms, and some consortia provide year-long opportunities. The national program's primary goal is to foster career development and increase the number of students who enter the STEM workforce.

B. Instrument Development

We developed a pre-post survey to assess the relationship between experiential learning experiences, STEM identity, and STEM career intention. The survey included eight scales to measure these constructs (Table 1).

TABLE 1
Survey Constructs

	Description	**Number of Survey Items**	**Cronbach's Alpha**
Experiential learning experience			
Authenticity scale	Extent to which students were engaged in the practices of a STEM professional during their program experience.	12	0.842
Student autonomy	Extent to which students made decisions about their experiential learning experience.	5	0.820
Mentoring best practices	Students' perceptions of the mentoring they received.	9	0.946
Community of Practice	Assessed the extent to which students perceive their STEM experience included practices such as connecting students with other students like them, fostering collaboration and peer support.	5	0.849
Mediating factors			
STEM self-efficacy	Assesses students' confidence to participate in STEM research or design and development activities, such as use STEM tools and/or instruments, create explanations for the results of a study or project, and figure out what data/observations to collect [17, 18, 19].	11	0.930
Academic competency	Adapted from Bong's [20] Self-Efficacy for Academic Achievement Scale, was used to assess students' perceived capability to master content in their STEM coursework.	6	0.936
STEM belonging	Adapted from University of Colorado Campus and Workplace Culture Survey [21], was used to measure students' feelings of recognition as a contributing member of the STEM community.	12	0.905
Outcome scales			
STEM identity	Assessed students' perception of themselves as someone who works in a STEM field [17, 18]	6	0.890
STEM career intentions	Assessed students' intentions to enter a STEM career or STEM-related graduate school.	4	0.689

C. Data Collection

We collected student survey data in each of six different academic term (fall, spring, summer) beginning in February 2023 and ending in August 2024. To identify and recruit Program students we requested a list of participating students and relevant contact information from each consortium at the six points in time. Consortia provided the names and related information (email, institution, award type, academic level, and award amount). Students received a $25 gift card for completing a pre-survey and another $25 gift card for completing the post-survey.

D. Participants

This study focuses on the undergraduate students who participated in the program from January 2023 to August 2024. Of the 4,934 undergraduate students enrolled, 1,123 completed a matched pre- and post-survey, representing a 22.8% response rate. Of those 1,123 undergraduate students who completed matched pre- and post-surveys, 1,119 were included in the final analysis. Four students were excluded due to missing data on key model variables (post-academic confidence, n = 1; mentoring, n = 3). All 52 consortia were represented in the dataset. The majority of students (89.7%) received direct funding for their experiential learning experience in the form of a stipend or employment. Funding ranged from $300 to $37,960 (students were eligible to receive multiple awards across program terms).

TABLE 2
Self-reported race and gender of undergraduate survey respondents (n = 1,119)

	Frequency	**Percent**
Gender		
Female	556	49.7%
Male	535	47.8%
Other/not identified	23	2.1%
Underrepresented students	290	25.9%
Discipline areas		
Science	318	28.4%
Engineering	536	47.9%
Other STEM	249	22.3%
Not identified	16	1.4%
Number of Awards		
1 award	900	80.4%
2 awards	188	16.8%
3 awards	27	2.4%
4 awards	4	0.4%
Award Type		
Internship	252	22.5%
Internship and Research	39	3.5%
Internship and Student Team	3	0.3%
Research	683	61.0%
Research and Student Team	16	1.4%
Student Team	120	10.7%
Unknown	6	0.5%

E. Data Analysis

To test the relationships between our hypothesized factors, we used structural equation modeling (SEM) using package Lavaan [22, 23] for R (R Core team 2025). SEM is well suited to this work because it allows simultaneous estimation of multiple regression equations, incorporates both pre- and post-measures by treating pre-scores as covariates and post-scores as outcome variables, and yields direct, indirect, and total effects among psychosocial constructs (self-efficacy, belonging, identity, and career intentions) [24]. We reviewed and cleaned our data following an initial analysis, and the results reported here reflect the corrected dataset.

We fit the model and evaluated its overall fit with the chi-square test of model fit, the comparative fit index (CFI), the Tucker-Lewis Index (TLI), the root mean square error of approximation (RMSEA) and its 90% confidence interval, and the standardized root mean square residual (SRMR). We also examined information criteria (AIC, BIC, and sample-size adjusted BIC) to describe the relative simplicity of the model.

In addition, we used regressions to look at each post-intervention construct (post-STEM self-efficacy, post-academic self-efficacy, post-belonging, post-STEM identity, and post-career intentions) in relationship to its corresponding pre-intervention measure and to the hypothesized predictors (authentic experiences, effective mentoring, autonomy, and community of practice), which allowed us to estimate the contributions of each factor. We also assessed the statistical significance of individual paths and the magnitude of their effects across outcomes. Finally, we used coefficients of determination (R^2) to summarize the proportion of variance explained in each variable, which provided an indicator of the model's explanatory power for post-intervention STEM perceptions, STEM identity, and career intentions.

To examine whether post-program outcomes differed by experience type, we classified students into three primary experience type categories based on their award records across all program terms: university-based research experiences (including research awards, fellowships, scholarships, and stipends), internships with industry or federal agency partners, and student team competitions. Students who participated in more than one experience type across program terms were classified into combined categories and excluded from this comparison. We then conducted one-way analyses of variance (ANOVA) to compare post-program means across the three primary experience types for each outcome variable. Where significant differences were found, we conducted post-hoc Tukey tests to identify which specific groups differed.

III. Results

The overall fit of our hypothesized model was good and shows a clear story: pre-program self-beliefs and program features shape post STEM self-efficacy and belonging, which in turn strengthens STEM identity, which then predicts post-program career intentions. Following a data correction, we updated the fit indices from the originally reported values. The CFI = 0.949 and TLI = 0.915, which indicated that the model reproduces the observed covariance structure well relative to the baseline model [25], [26]. The RMSEA = 0.074 (90% CI [.066, .083]) and SRMR = 0.026, indicate that the model has an acceptable absolute fit [25], [26]. Next, we looked at how the model's pre-perception and program variables predicted the mediating variables and outcomes. These outcomes are summarized below.

A. Effects of Pre-Perceptions and Program Variables on Mediators

1) STEM Self-Efficacy: Our model explained 59% of the variance in students' post-STEM self-efficacy. While students' pre-STEM self-efficacy had the strongest association with their post-STEM self-efficacy ($\beta = 0.578$, $p < .001$), program features remained important for building STEM self-efficacy. In particular, students who reported higher levels of engaging in authentic STEM practices reported higher post-STEM self-efficacy after participating in the program ($\beta = 0.220$, $p < .001$). Similarly, students who reported higher levels of autonomy to make choices, set goals, or decide how to approach tasks also reported higher post-STEM self-efficacy ($\beta = 0.063$, $p = .002$). Finally, students who reported being involved in a community of practice at higher levels also reported higher post-STEM self-efficacy (β = 0.104, $p < .001$). Mentoring and funding amount were not significantly associated with post-STEM self-efficacy.

TABLE 3
Predictors of post-STEM self-efficacy

Predictor	Estimate (b)	Std.Err	z-value	p	Std.lv	Std.all (β)
Pre-STEM self-efficacy	0.555	0.021	26.340	< **0.000**	0.555	0.578
Funding	0.002	0.005	0.370	0.711	0.002	0.007
Authentic STEM practices	0.234	0.024	9.765	< **0.000**	0.234	0.220
Effective mentoring	0.023	0.022	1.024	0.306	0.023	0.022
Autonomy	0.186	0.061	3.061	**0.002**	0.186	0.063
Community of practice	0.116	0.024	4.816	< **0.000**	0.116	0.104

2) Academic Self-Efficacy: Our model explained 45% of the variance in students' post-academic self-efficacy. Pre-academic self-efficacy was by far the dominant predictor of post-academic self-efficacy in our model (β = 0.621, $p < .001$). Most program features had non-significant impacts on post-academic self-efficacy. However, autonomy had a significant association (β = 0.074, $p = .002$) as did students' feelings that they were part of a community of practice (β = 0.089, $p < .001$). Both predicted higher post-academic self-efficacy. Authentic STEM practices, mentoring, and funding amount were not significant predictors of post-academic self-efficacy.

TABLE 4
Predictors of post-academic self-efficacy

Predictor	Estimate (b)	Std.Err	z-value	p	Std.lv	Std.all (β)
Pre-academic self-efficacy	0.628	0.023	26.853	< **0.000**	0.628	0.621
Funding	-0.001	0.004	-0.309	0.757	-0.001	-0.007
Authentic STEM practices	0.002	0.018	0.136	0.892	0.002	0.003
Effective mentoring	0.030	0.018	1.670	0.095	0.030	0.041
Autonomy	0.151	0.049	3.095	**0.002**	0.151	0.074
Community of practice	0.069	0.019	3.545	**<0.000**	0.069	0.089

3) STEM Belonging: Our model explained 57% of the variance in students' post-STEM belonging. Pre-STEM belonging was the dominant predictor of post-STEM belonging (β = 0.621, $p < .001$), but both effective mentoring (β = 0.179, $p < .001$) and community of practice (β = 0.104, $p < .001$) contributed to students' feelings of belonging. Authentic STEM experiences, autonomy, and funding amount were not significant predictors of post-STEM belonging.

TABLE 5
Predictors of post-STEM belonging

Predictor	**Estimate (b)**	**Std.Err**	**z-value**	**p**	**Std.lv**	**Std.all (β)**
Pre-STEM belonging	0.607	0.021	28.808	**< 0.000**	0.607	0.621
Funding	-0.003	0.004	-0.824	0.410	-0.003	-0.016
Authentic STEM practices	0.005	0.018	0.264	0.791	0.005	0.006
Effective mentoring	0.151	0.019	7.943	**< 0.000**	0.151	0.179
Autonomy	0.028	0.050	0.569	0.569	0.028	0.012
Community of practice	0.094	0.020	4.632	**< 0.000**	0.094	0.104

B. Mediated Effects on STEM Identity and Career Decidedness

1) STEM Identity: Our model explained 59% of the variance in students' post-STEM identity. The first set of paths indicates that post-STEM identity is strongly and positively associated with all predictors. Specifically, higher pre-STEM identity is associated with higher post-STEM identity ($\beta = 0.591$, $p < .001$), which indicates students have stability in their STEM identity over time. Post-STEM self-efficacy ($\beta = 0.110$, $p < .001$), post-academic self-efficacy ($\beta = 0.159$, $p < .001$), and post-belonging ($\beta = 0.149$, $p < .001$) are each uniquely and positively related to post-STEM identity; students who report more positive program experiences and stronger engagement also report stronger STEM identity after participating in the program.

TABLE 6
Structural Equation Model estimates predicting post-STEM identity

Predictor	**Estimate (b)**	**Std.Err**	**z-value**	**p**	**Std.lv**	**Std.all (β)**
Pre-STEM identity	0.577	0.021	27.437	**< 0.000**	0.577	0.591
Post-STEM self-efficacy	0.092	0.018	5.158	**< 0.000**	0.092	0.110
Post-academic self-efficacy	0.192	0.026	7.331	**< 0.000**	0.192	0.159
Post-belonging	0.155	0.022	7.164	**< 0.000**	0.155	0.149

2) STEM Career Intentions: Our model explained 36% of the variance in students' post-career intentions. The second set of paths shows that post-career intentions are positively predicted by both pre-career intentions and post-STEM identity. Specifically, higher initial career intentions are associated with higher post-career intentions ($\beta = 0.420$, $p < .001$), while post-STEM identity is also a strong, positive predictor of post-career intentions ($\beta = 0.335$, $p < .001$). Together, these results indicate that both students' initial career intentions and their developed STEM identity during the program are important in explaining variance in post-program career intentions.

TABLE 7
Predictors of post-career intentions

Predictor	**Estimate (b)**	**Std.Err**	**z-value**	**p**	**Std.lv**	**Std.all (β)**
Pre-career intentions	0.352	0.021	16.938	**< 0.000**	0.352	0.420
Post-STEM identity	0.366	0.027	13.631	**< 0.000**	0.366	0.335

Overall, the model explained substantial variance in the mediators and outcomes. The predictors accounted for 59% of the variance in post-STEM self-efficacy ($R^2 = .592$), 45% in post-academic self-efficacy ($R^2 = .446$), and 57% in post-STEM belonging ($R^2 = .565$). The model also explained 59% of the variance in post-STEM identity ($R^2 = .594$) and 36% of the variance in post-career intentions ($R^2 = .358$).

C. Differences by Experience Type

To address whether post-program outcomes differed by experience type, we compared post-program means across three primary experience types: university-based research experiences (n = 683), internships with industry or federal agency partners (n = 252), and student team competitions (n = 120). Table X presents post-program outcome means by experience type.

TABLE 8
Post-program outcome means by experience type

Outcome	**Internship (n=252)**	**Research (n=683)**	**Student Team (n=120)**
STEM Self-Efficacy	4.34	4.18	4.56
Academic Self-Efficacy	5.23	5.27	5.33
Belonging	5.05	5.01	4.81
STEM Identity	5.00	4.96	5.03
Career Intentions	4.66	4.69	4.79

Note. All outcomes measured on a 7-point Likert scale.

One-way ANOVA results indicated significant differences across experience types for two outcomes: post-STEM self-efficacy ($F(2, 1052) = 9.28$, $p < .001$) and post-belonging ($F(2, 1052) = 4.03$, $p = .018$). Academic self-efficacy ($F(2, 1052) = 0.92$, $p = .398$), STEM identity ($F(2, 1052) = 0.39$, $p = .677$), and career intentions ($F(2, 1052) = 0.86$, $p = .422$) did not differ significantly across experience types.

Post-hoc Tukey tests for STEM self-efficacy showed that student team participants reported significantly higher post-program STEM self-efficacy than research students (difference = 0.39, $p < .001$), no significant differences were found between internship and research students ($p = .053$) or between student team and internship students ($p = .102$). For belonging, student team participants reported significantly lower post-program belonging than both internship students (difference = -0.24, $p = .017$) and research students (difference = -0.20, $p = .028$), while internship and research students did not differ significantly from one another ($p = .774$).

These findings suggest that while experience type does not significantly affect STEM identity or career intentions, the type of experience may shape how students develop STEM self-efficacy and belonging. Student team competitions appear to build technical confidence through performance and achievement, while research and internship experiences may more effectively foster the community connections and mentoring relationships that support belonging. These patterns are discussed further in the Discussion section.

IV. Discussion

Our findings reinforce and extend prior work showing that well-designed experiential learning can be a powerful driver of STEM self-efficacy, belonging, and identity, and ultimately of students' intentions to pursue STEM careers [8, 14]. The structural equation model indicated that pre-program beliefs and program features, across 52 consortia, jointly shaped post-program STEM self-efficacy and belonging, which in turn predicted STEM identity. STEM identity then predicted students' post-program career intentions. The model explained a large proportion of the variance in each construct ($R^2 = 0.592$ for post-STEM self-efficacy, 0.446 for post-academic self-efficacy, 0.565 for STEM belonging, 0.594 for STEM identity, and 0.358 for career intentions). Notably, while funding amount did not directly predict psychosocial outcomes in our model, prior evaluation of this program has shown that financial support provides critical relief that allows students to concentrate on their experiential learning without the distraction of financial worries, which may indirectly enable the psychosocial gains we observed. Our study indicates that experiential design choices can meaningfully influence key psychosocial precursors to STEM persistence across many sites and program types.

A. Contributions to Theory

Our results support a cohesive view of experiential learning and STEM identity theory. Consistent with prior research on STEM identity [27], competence beliefs (STEM self-efficacy and academic self-efficacy) and relatedness (belonging) emerged as important psychosocial constructs that, when supported through program features, contributed to stronger post-program STEM identity. This finding is consistent with Estrada et al. [28], who found that self-efficacy and identity together mediate the effects of science support programs on students' career outcomes, and with Dresser et al. [14], who demonstrated that structured experiential programs increase career interest particularly among underrepresented students.

Our model also highlighted that experiential learning features affect psychosocial mediators differently. Authentic STEM practices most strongly predicted STEM self-efficacy, consistent with Bandura's [9] self-efficacy theory, which identifies mastery experiences as the most powerful source of efficacy beliefs. When students engage directly in disciplinary tasks such as designing studies, troubleshooting experiments, and communicating results, they build the kind of firsthand competence experience that most powerfully shapes their confidence. This finding replicates prior work showing that authentic research experiences are a particularly effective driver of STEM self-efficacy [8, 9, 10].

Community of practice and effective mentoring more strongly predicted belonging and identity. This is consistent with prior research demonstrating that structured programs providing peer interaction, mentoring, and recognition strengthen students' sense of belonging in STEM [11, 12] and with LaCosse et al. [12], who found that social belonging interventions produce lasting improvements in STEM outcomes. The finding that mentoring specifically predicted belonging, while authenticity primarily predicted self-efficacy, suggests that these two program features operate through distinct psychosocial pathways, a distinction that has important implications for program design.

B. Experience Type Differences

We also examined whether post-program outcomes differed by experience type. Students participated in three primary experience types: research experiences ($n = 683$), internships with industry or federal agency partners ($n = 252$), and student team competitions ($n = 120$). ANOVA results indicated significant differences in post-program STEM self-efficacy ($F(2, 1052) = 9.28$, $p < .001$) and belonging ($F(2, 1052) = 4.03$, $p = .018$) by experience type, while academic self-efficacy, STEM identity, and career intentions did not differ significantly across groups. Post-hoc Tukey tests revealed that student team participants reported significantly higher STEM self-efficacy than research students ($p < .001$) but significantly lower belonging than both internship ($p = .017$) and research students ($p = .028$). These findings suggest that competition-based experiences may build technical confidence through performance and achievement, while research and internship experiences more effectively foster the community connections and mentoring relationships that support belonging. Importantly, STEM identity and career intentions did not differ significantly across experience types, suggesting that the program's core outcomes are achievable across multiple experiential learning formats. Future research should examine the mechanisms through which different experience types shape psychosocial outcomes and explore whether these differences persist over time.

C. Implications for Program Design and Practice

For STEM educators, our findings stress the importance of systematically designing experiential learning opportunities that integrate authentic STEM work, effective mentoring, student autonomy, and a supportive community of practice that includes other students as well as faculty. Our findings provide large-scale evidence that each feature contributes uniquely to students' psychosocial development, and that their combined effect is substantial.

First, the strong link between authentic practices and STEM self-efficacy suggests that experiential projects should actively engage students in as many core disciplinary tasks as possible. Student activities should go beyond simple tasks like data entry or routine testing. Instead, students should be involved in the full range of professional activities appropriate to their experience type. For research-based experiences, this means engaging students in designing studies, developing hypotheses, troubleshooting experiments, analyzing data, and communicating results to professional audiences. For engineering and design-based experiences, this means engaging students in defining problems, prototyping solutions, testing and iterating on designs, and presenting findings to technical and non-technical audiences. Projects should also support students' professional skills such as project management, leadership, and writing.

Second, the significant links between community of practice and mentoring to belonging and identity suggest that experiential learning programs need to provide regular, intentional interaction among students and between students and faculty or industry mentors. Programs can build opportunities for student interaction intentionally through weekly lab meetings where students share progress and receive feedback, peer mentoring structures that pair newer students with more advanced peers, and program-wide events such as research symposia and networking receptions. Prior research has found that emphasizing community like this increases student belonging and persistence in STEM [8, 11]. Programs can also provide effective mentoring by including multiple forms of support: guidance and encouragement, skill development and opportunities for advancement, and co-authoring experiences [29]. Research also indicates that students benefit from having access to a broad network of mentors [29].

Third, the connections between autonomy and both STEM self-efficacy and academic self-efficacy suggest that programs should provide students with meaningful opportunities to define problems, choose methods, or shape the direction of their work. Greater student autonomy does not require giving students complete independence, but rather designing scaffolded opportunities for decision-making that grow as students develop their skills. For example, early in a program students might choose among several project directions, while more advanced students might design their own research questions or lead a component of a larger project independently.

Finally, although funding amount was not a significant predictor of psychosocial outcomes in our model, nearly 90% of students in our sample received financial support through stipends or paid positions. This financial support likely reduces students' need for outside employment and enables fuller engagement in their experiential learning experience, which may indirectly support the psychosocial outcomes we observed. Program designers and institutions should consider financial support as an important structural feature that enables students, particularly those from lower-income backgrounds, to fully participate in experiential learning opportunities.

Together, our results suggest that experiential programs should be intentionally designed as mentoring-rich, autonomy-supportive communities of practice in which students regularly engage in authentic disciplinary work, share their contributions publicly, and are recognized as valued members of the STEM community. Institutions that cannot offer full research experiences may still incorporate many of these features through course-based undergraduate research experiences (CUREs), structured internship programs with mentoring components, or multi-institutional networks that connect students across institutions and disciplines.

D. Equity and Broadening Participation

Prior research shows that STEM self-efficacy, sense of belonging, and STEM identity are particularly important for women and racially or ethnically underrepresented students in STEM [28, 30, 31]. By demonstrating that experiential features such as authentic work, community of practice, and mentoring are strongly associated with these constructs in a large, national program, our findings suggest that high quality experiential learning can serve as a meaningful mechanism for broadening participation in the STEM workforce. In addition, while the amount of funding that students received did not directly predict gains in STEM self-efficacy, belonging, or identity, our evaluation of the national program pointed to the importance of funding for students to participate in a research opportunity or internship. For many, financial support was essential for their participation. From an equity perspective, ensuring that experiential learning is not limited to students who can afford unpaid or low-paid positions remains a key design consideration.

E. Limitations

This study had several limitations. First, while we know about undergraduate students' aspirations to pursue a STEM career, we do not know which students who participated in this study will eventually do so. Continuing the study for a longer time period would have provided an opportunity to correlate findings related to STEM self-efficacy and identity to actual career outcomes. Second, this evaluation did not use a random sample of students and therefore we may have introduced bias into our results. For example, only students who had a positive experience may have completed pre- and post-surveys. We do not know what non-sampled students may have reported and thus we cannot calculate the non-response bias. Third, while our sample included students across a range of STEM disciplines including engineering, science, and other STEM fields, our model did not examine whether the relationships between experiential learning features and psychosocial outcomes differ across disciplines. Future research should examine whether discipline-specific factors moderate the pathways we identified. Fourth, our study did not account for the duration of students' experiential learning experiences, which ranged from one semester to a full year across consortia, or whether participation was required for program completion or pursued voluntarily. Both duration and the voluntary nature of participation may influence students' engagement and the psychosocial outcomes we observed, and warrant examination in future studies.

F. Conclusion

Our study demonstrated in a large, national experiential learning program that when students participate in authentic STEM practices, receive effective mentoring, have autonomy to make decisions about their research or design project, and operate within a community of practice, these activities work together to increase their STEM self-efficacy, academic self-efficacy, and belonging. These changes in turn supports stronger STEM identity and clearer intentions to pursue STEM careers. Our results also suggest that experiential programs should be intentionally structured as mentoring-rich, autonomy-supportive communities where students regularly share their work and are recognized as contributors.

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