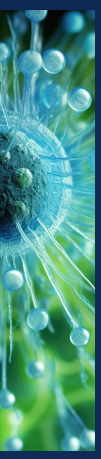
STEM STUDENTS & THEIR SENSE OF BELONGING:

S-STEM PROGRAMS' PRACTICES & EMPIRICALLY BASED RECOMMENDATIONS

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



AAAS | S-STEM REC

NSF

The AAAS S-STEM Resource & Evaluation Center (REC) seeks to cultivate a network of NSF S-STEM stakeholders and further develop the infrastructure needed to promote the exchange of ideas, resources, opportunities, and knowledge related to the effective strategies and practices to increase the number of academically talented students with financial need obtaining degrees in STEM and entering the STEM workforce.

Additional resources including NSF proposal preparation resources, blogs from invited experts in the field, and information about our annual S-STEM scholars' conference are available on our website. I invite you to visit our website and to join the network of growing S-STEM stakeholders as we increase opportunities for all people and build a more robust and excellent STEM enterprise.

I would like to thank the National Science Foundation for their ongoing support as we seek to advance science and serve society.

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This material is based upon work supported by the National Science Foundation under Grant No. 2224093. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Belonging is improved by greater integration into the STEM community.

Introduction

The purpose of the S-STEM REC's Programmatic Deep Dive series is to build the capacity of S-STEM awardees by identifying unmet knowledge needs or barriers to success and by creating resources to help address those needs or remove those barriers. In its inaugural year, the S-STEM REC focused on students' science identity. Specifically, this programmatic deep dive explores how experiencing a "sense of belonging" plays a role in S-STEM scholars' success.

This report reviews the extant literature on developing sense of belonging for STEM students and synthesizes qualitative and quantitative data from current and past S-STEM awardees. Using a concurrent mixed-methods research design, we represent the current state of STEM sense of belonging incorporation in S-STEM programs, describe the effective practices of programs, and make recommendations for how colleges and universities could develop sense of belonging for students from low-income backgrounds within STEM programs and thereby bolster student success and persistence. The findings presented honor the unique contexts of various institutional types, with a specific focus on how students' sense of belonging may be mediated or moderated by institutional factors like research intensity and mission, whether the institution is minority serving, and whether it is a two- or four-year institution. The words of S-STEM program Principal Investigators, reflecting their thoughts and experiences, are distributed throughout this report, both highlighting and enhancing the empirical literature.

First, the topic and the population are described. Then, empirical research on S-STEM program actions related to scholars' sense of belonging is presented. Finally, empirically derived effective practices from published research are incorporated and presented within the recommendations for practice.

Sense of Belonging

STEM (science, technology, engineering, and mathematics) students' academic performance and well-being are impacted by their sense of belonging. This simple statement is immersed in a complex world of psychological need, perception, individual actions, and institutional resources.

Common perceptions for students who may qualify for S-STEM scholarships include being unwelcome and having anxiety that they will confirm negative stereotypes, known as the stereotype threat (1). Nontraditional college students, students from low-income backgrounds, and students from underrepresented minority groups experience higher levels of stereotype threat than their traditional peers, which impacts both their academic performance and their well-being. Students influenced by stereotype threat lower their own academic self-efficacy, and their academic performance declines as a consequence.

Suggested citation: STEM Students & Their Sense of Belonging: S-STEM Programs' Practices & Empirically Based Recommendations (S-STEM REC American Association for the Advancement of Science, 2023).

A QUOTE FROM THE LITERATURE

"Students have to come to see themselves as a member of a community of other students, faculty and staff who value their membership — that they matter and belong. Thus, the term 'sense of belonging'" (2).

STEM students experience belonging differently given their individual characteristics. A person's background and demographic characteristics intersect and intermingle, influencing their thoughts, values, and actions even if they demonstrate STEM capability (3-7). As an illustration, a Hispanic woman who qualifies for an S-STEM scholarship, while having demonstrated high scientific academic ability, may doubt themselves, their ability, and their belongingness more than does the traditional STEM student. These perceptions are associated with decreased morale and confidence. Those decreases predict academic decline and students switching from STEM and/or leaving higher education. An individual's belonging is predictive of their persistence and performance, and their belonging is improved by greater integration into the STEM community (8). STEM students' sense of belonging can serve as a leading indicator of academic performance and persistence.

S-STEM PROGRAMS IN THEIR OWN WORDS

"If they [students] don't feel like they belong, it is much easier for them to slowly slip away and not ask for help. Without a 'sense of belonging', the program doesn't function well."

Low-Income Population Needs and Benefits

Low-income (LI) background STEM students often face obstacles traditional college students do not (e.g., stereotype threats, imposter syndrome, less time and fewer financial resources), and these obstacles are not reflective of their capabilities or dedication (10). Nontraditional actions are required from institutions and STEM programs to provide an educational environment in which students from LI backgrounds will thrive. These actions lead to environments that align with the values, identities, and strengths of LI students and account for the opportunity gaps those students often experience. There is no single panacea that addresses all possible obstacles. STEM students from LI backgrounds significantly benefit from and may even require additional institutional resources. After decades of empirical research, several strategies (e.g., mentoring, undergraduate research experience, cognitive interventions) to improve the educational outcomes for LI background STEM students are known to produce substantial positive effects (9).

Individual and cultural values that LI students bring to the STEM academic world can differ from those of traditional higher education students. These value differences lead to nontraditional students feeling less belonging, integrating less, and performing worse than they are capable (11-13). A nontraditional cultural value includes being more collectivist (or less individualistic) with goals and accomplishments. LI students often feel a need to contribute to their local community more than does the traditional STEM student (11). Another different value stems from LI and intersecting demographics (e.g., gender) and the rejection of a competitive educational and grading environment (10, 14). When STEM students have incongruent cultural values, those students feel less a part of the community and do not integrate into it well (11-13).

A QUOTE FROM THE LITERATURE

"They also tend to be older, less likely to receive financial support from parents, and more likely to have multiple obligations outside college, like family and work, that limit their full participation in the college experience" (9).

A sense of belonging, especially for LI nontraditional STEM students, can predict persistence rates (8, 15, 16). STEM students who belong, or in other words who feel a part of their institution's STEM community, are more likely to participate in educational activities. This holds true for students in Minority Serving Institutions (MSIs) and teaching or research focused schools (4).

However, belonging does not equally affect all student populations in terms of academic performance (17). For instance, belonging can be influenced by high school experiences for women in comparison with men (18-20).

S-STEM PROGRAMS IN THEIR OWN WORDS

"When students are worried about basic needs (food, transportation, shelter), it's a big problem."

In addition, two-year STEM students persist and succeed with academic preparation and assistance, but often a sense of belonging is not predictive of academic performance (21, 22). Sense of belonging is an important factor for individuals who do not have a cultural connection to STEM or higher education in four-year and graduate programs (5, 12).

Notably, sense of belonging is not predetermined but is malleable and can be developed with interventions and intentional curricular and cocurricular design (e.g., mentoring, undergraduate research experiences, service-learning courses), especially for LI and first-generation (first-gen) students (23). Even brief psychological interventions can significantly impact academic performance, persistence, and well-being (24).

KEY TAKEAWAYS

- LI STEM students often have a low sense of belonging.
- STEM students' sense of belonging is predictive of performance and persistence at four-year colleges.
- Institutions and STEM programs can improve students' sense of belonging through various empirically based practices.

RESOURCES

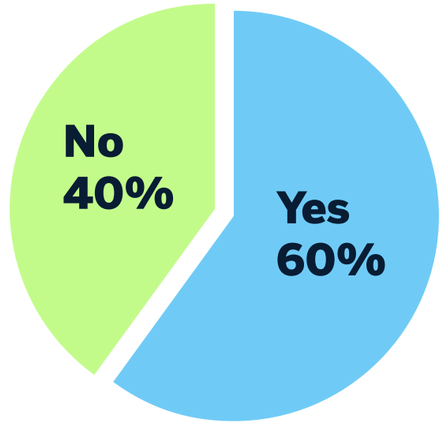
- College Students' Sense of Belonging: A Key to Educational Success for All Students (13)
- Ten simple rules for successfully supporting first-generation/low-income (FLI) students in STEM (25)
- Adopting a multi-systems approach: examining the academic belongingness of first-generation college students with multiple stigmatized identities in STEM (26)

S-STEM Programs and Effective Practices

Given its connections to increased academic and affective outcomes, students' sense of belonging is important to measure and track. A survey of S-STEM programs (N=105) shows a majority are monitoring their students' sense of belonging. The survey respondents are representative of the institutional characteristics (MSI, research focus, two- or four-year) of active S-STEM programs. How and when institutions respond vary significantly. Most programs (60% of the respondents) are monitoring and taking action to improve S-STEM scholars' sense of belonging because of and through their S-STEM program, and are not reliant on preexisting institutional practices or programs.

Delving deeper into the data reveals that the proportion of S-STEM programs measuring scholars' sense of belonging differs based on institutional characteristics. Similarly, institutions' actions (i.e., intervention programs) differ by their institutional characteristics (MSI, research focus, two- or four-year, and locality) (27). Sixty-one percent of reporting MSIs measured sense of belonging. Less than half of research-focused institutions were specifically assessing belonging, while 75% of primarily undergraduate institutions measured belonging. About half of reporting suburban and rural institutions measured scholars' belonging, while city- and town-located institutions measured S-STEM scholar belonging at much higher rates, 63% and 83% respectively.

Most institutions only measured students' sense of belonging once per academic year and most frequently did so via individual or group meetings. When formal measurements were taken, a wide variety of validity measures were applied. The most reported validated instrument used was the Science Motivation Questionnaire's Sense of Belonging in Science, Technology, Engineering, and Mathematics Domains scale (24, 25). More often, S-STEM programs created their own measures by selecting items from various scales and subscales. Example items from the more frequently used measures include items like "Learning science makes my life more meaningful," "I generally feel that people accept me," and "How do you feel about your major?" (28). Thirty percent of reporting institutions reported that they take no action based on low belonging scores. An equal 30% reported an active intervention program to bolster a scholar's sense of belonging. The remaining programs were still determining what, if any, course of action to take given their early status in the program or have not had any



DOES YOUR S-STEM PROGRAM MEASURE SENSE OF BELONGING?

scholars with a low score on belonging. Interestingly, in our sample, almost no MSI reported taking no action based on their belonging measurements, in contrast to the 37% of non-MSIs that reported having no plan of action.

There are evidence-based and promising practices that S-STEM programs can and do utilize to increase S-STEM scholars' sense of belonging. Nearly every S-STEM program uses more than one approach (see chart: **S-STEM Strategies to Develop Sense of Belonging** on the following page). Ninety-six percent of S-STEM programs report using faculty mentoring and 86% utilize academic advising as the two most frequent strategies employed.

There is a plethora of empirically derived effective practices in the research literature that an institution can adapt to their S-STEM scholar population's needs and institutional requirements. A multistudy systemic review found all of the practices listed below have empirical support (29). This allows S-STEM programs to select which types of interventions they have resources for and know will be beneficial to their scholars. Consistent with the research, S-STEM programs across all institution types and characteristics utilize a variety of interventions for their scholars.

TABLE: INTERVENTION ACTION BY MSI TYPE

MSI Type	Total (N)	Take Action (%)	No Action (%)
Not Qualified	46	78	22
Strengthening Institutions Program	22	64	36
Hispanic-Serving Institutions	6	50	50
Historically Black Colleges and Universities	2	50	50
Native American Nontribal Institutions	1	100	0
Predominantly Black Institutions	1	100	0
Multiple MSI Types	20	85	15

TABLE: INTERVENTION ACTION BY 2 VS 4 YEAR

Level	Total (N)	Take Action (%)	No Action (%)
2-year	16	81	19
4-year	82	73	27

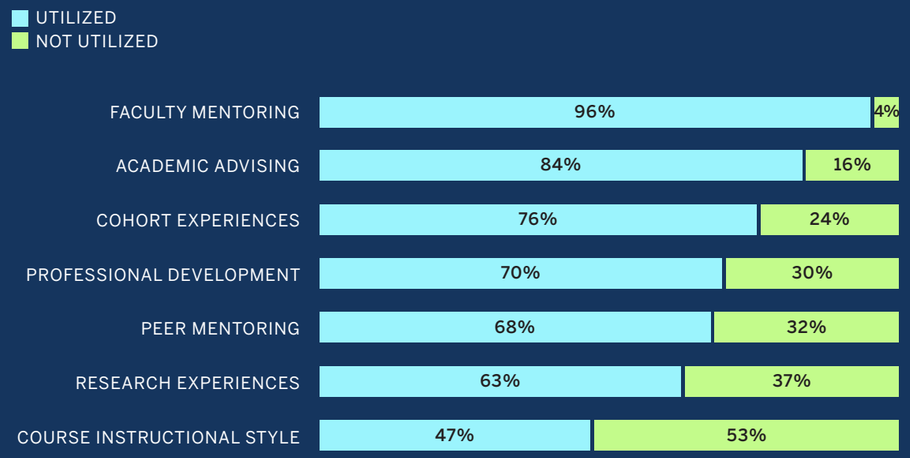
TABLE: INTERVENTION ACTION BY RESEARCH FOCUS

Level	Total (N)	Take Action (%)	No Action (%)
Primarily undergraduate	53	74	26
Research-focused	45	76	24

S-STEM PROGRAMS IN THEIR OWN WORDS

"There still is a sense of shame when they fail. Even though we want to help, students won't tell us they are struggling unless we reach out."

S-STEM Strategies to Develop Sense of Belonging



Faculty and Peer Mentoring

The most common intervention reported by S-STEM programs was student mentoring. S-STEM award programs match mentors and mentees using various methods including shared research and/or personal interests, mentor selection, and random assignment. There are both peer and faculty mentoring approaches. STEM students from underrepresented backgrounds report that meeting STEM professionals of their own gender and ethnicity is particularly beneficial for them. Matching mentors and mentees based on demographic backgrounds does not guarantee improved academic performance but does improves belonging and persistence in STEM (30). There are research-based faculty mentoring strategies and matching techniques that S-STEM programs use to ensure first-gen and other nontraditional students receive effective mentoring. Matched mentoring is not a guarantee of effectiveness, especially if mentors are not culturally aware of their mentees' values and circumstances (29, 31).

S-STEM PROGRAMS IN THEIR OWN WORDS

"After using industry mentors and receiving feedback from both the industry mentors and the students, we changed to a more near-peer mentoring situation."

Peer mentors have a greater impact in the early years of an S-STEM student's academic career, while faculty mentors become more influential in later years (10). Integrated mentoring and research experiences were key to improving student persistence rates (32). Studies on peer coaching or mentoring have found that it assists early career scientists. Although this research was specifically for women and scientists from underrepresented groups, the underlying disadvantages experienced by those groups intersect with those of first-gen and LI background STEM students. High-quality mentor-mentee matching can create a support network boosting participation in STEM while, conversely, mentors without formal mentor training can lead to worse relationships (33). High-quality mentors craft relationships and understanding of their mentees' backgrounds, concerns, and interests. Mentors should also be knowledgeable about resources available to help the mentees (34).

S-STEM PROGRAMS IN THEIR OWN WORDS

"We are revamping our mentorship program to use a group mentoring model. We'll have mentoring teams with 2-3 faculty mentors and 5-6 students. They will meet to discuss their projects, their classes, and their career goals. We are also bolstering our support for projects by holding monthly meetings for all students in our cohort. They will come together to learn about research and presentation skills. We hope this will help the students form a stronger community."

RESOURCES

- Entering mentoring: a seminar to train a new generation of scientists (33)
- National Academies of Science, Engineering, & Medicine: The Science of Effective Mentoring in STEMM (35, 36)
- How a Mentorship Program Adapted and Built Connections to Last (37)
- Mentoring Undergraduate Students (38)
- Creating a mentoring culture in graduate training programs: Training and Education in Professional Psychology (39)

Professional Development

Most S-STEM programs report providing professional development activities (e.g., resume building workshops, interview preparations, networking), as LI background students often benefit from instruction on how to be a professional in STEM. These nontraditional students likely do not have the cultural knowledge of how to become employed as a STEM professional. Workshops, seminars, and any type of professional development activity help students learn skills necessary to be competitive in the job application process and to be successful as a STEM professional.

The S-STEM program at Augusta University uses both mentoring and professional development activities. Utilizing those interventions, they reported scholars achieving greater academic performance (GPA) in comparison to a control group.

RESOURCES

- The Role of Soft Skills in STEM: Why Employers Are Looking Beyond Technical Proficiency (40)
- Strategically Addressing the Soft Skills Gap Among STEM Undergraduates (41)
- Professional Development: Shaping Effective Programs for STEM Graduate Students (42)

Undergraduate Research Experience

Most reporting S-STEM programs provided undergraduate research experiences. Research experiences help students address the stereotype threats they perceive when demonstrating their accomplishments in research settings (8, 29, 43). A longitudinal study found that underrepresented minorities improve their STEM persistence with participation in undergraduate research (43).

S-STEM PROGRAMS IN THEIR OWN WORDS

"Commuter campus research experiences work best when built into classes that count towards students' majors. Optional activities tend to be under enrolled."

S-STEM programs at Naugatuck Valley Community College and University of North Carolina at Pembroke report using mentoring, professional development activities, and research experiences. These two schools differ in their student populations (MSI vs. non-MSI) and school characteristics (two and four year). Both reported to the S-STEM REC that their scholars saw improved academic performance,

S-STEM PROGRAMS IN THEIR OWN WORDS

"Students reported that field trips and learning experiences supported their networking while also providing them insight into different STEM career opportunities" (44).

retention, and graduation rates in comparison to their respective control groups.

RESOURCES

- Undergraduate research experiences: Impacts and opportunities (45)
- Increasing Persistence of College Students in STEM (46)
- Expanding Underrepresented Minority Participation (47)
- Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities (48)

Course Instructional Style

Less than half of S-STEM responding programs use nonlecture-based courses or interactive courses for their scholars. Interactive courses are more effective at incorporating nontraditional STEM students (49, 50). The traditional lecture-based courses and grading schemes (e.g., low grades and grade curving) are discouraging and ineffective for nontraditional STEM students (14, 51). Examples of interactive courses incorporate real-time audience feedback (e.g., clickers), simulations, and group discussions (10). Coupled with adaptations that many institutions implemented during the COVID pandemic, traditional courses and grading practices left many students struggling to connect with school and STEM. On the other hand, courses that are more interactive, provide faster instructor feedback on work, and are less obtuse regarding the grading scheme often engage LI and other nontraditional students to a greater effect (14).

S-STEM PROGRAMS IN THEIR OWN WORDS

"Several students said that the in-person meetings of the STEM project significantly increased their connection to other students with similar interests."

Several institutions with different student populations reported incorporating interactive courses. The courses were part of multiple intervention types being used to increase their scholars' sense of belonging and academic outcomes. The S-STEM program at the University of North Carolina at Greensboro uses interactive courses in addition to mentors, research experiences, and professional development activities. They reported positive scholar attitudes and increased sense of belonging from those who transfer from the local community college. The S-STEM program at University of Colorado – Denver's Environmental Stewardship of Indigenous Lands (ESIL) used mentoring, interactive courses, and research experiences to bolster S-STEM scholars' belonging. Additionally, the S-STEM program from the College of Southern Maryland utilized professional development experiences, mentoring, interactive courses, and research experiences to assist their scholars. These institutions represent different MSIs, both two- and four-year colleges, all improving their scholars' sense of belonging and related academic outcomes.

RESOURCES

- Active learning-based STEM education for in-person and online learning (53)
- Active learning increases student performance in science, engineering, and mathematics (54)

S-STEM PROGRAMS IN THEIR OWN WORDS

"Building community is crucial to Indigenous students' feelings of connection, and ESIL increased an appreciation of Indigenous perspectives and provided the necessary skills and self-awareness to navigate cross-cultural spaces and conversations" (52).

Cohort Experiences

Cohort-based STEM programs, like the Meyerhoff Scholars Program, create environments in which STEM students can thrive (55, 56). Programs similar to the Meyerhoff Scholars Program, Millennium Scholars Program, and Chancellors Science Scholars Program house each cohort together and provide research and other common educational activities (e.g., workshops, seminars, student debates), class schedules, mentoring, and academic advising. The programs themselves often have highly selective (e.g., GPA, student interviews) admissions policy criteria. These programs require attention and resources that other students do not receive. However, it does not take a resource-intensive cohort (or living-learning) model to impact scholars (40, 41). A living-learning approach combined with an undergraduate research experience in the first or second year resulted in higher retention and academic success for underrepresented and first-generation STEM students in comparison to a matched student group. Participating students shared "common goals and majors," facilitating community building. This study was conducted at a research-focused university (42).

One research-focused northeastern university tested a modest living-learning model. Being part of a learning community improved GPA and retention relative to a control group. Students also demonstrated improved academic and social experiences in their first few years. Due to this, their academic integration and success improved. However, the research found that if students are not part of a *diverse* cohort, learning communities can produce the unintentional effect of limiting students' interaction and exposure with the larger, more diverse student body (58).

S-STEM programs at University of Washington Seattle, University of Washington Tacoma, and St. John Fisher University used professional development activities, mentoring, and interactive courses to bolster their students' academic performance, retention, and graduation rates. These are all universities with different MSI qualifications, research focuses, and localities. In comparison to a control group, the scholars participating in activities had improved academic performance (GPA) and retention rates (43).

KEY TAKEAWAYS

- Most S-STEM programs measure their students' sense of belonging.
- There are effective practices to improve S-STEM students' sense of belonging.
- Institutions all employ similar approaches, regardless of characteristics like MSI, research focus, and two- or four-year.
- Mentoring is the most common intervention.

RESOURCES

- Replicating Meyerhoff for inclusive excellence in STEM (56)
- The Impact of Varying Living-Learning Community Models (58)

S-STEM PROGRAMS IN THEIR OWN WORDS

"Accepting students from such a wide range of majors (all STEM) made it next to impossible to have cohort activities. In the future I would recommend more narrowly focused programs."

Additional Considerations

An individual's mindset can be instrumental in adapting to an unfamiliar environment. LI STEM students demonstrated significant gains in belonging and persistence with some cognitive assistance (60, 61). A brief intervention early on can have long-term effects on a variety of outcomes (e.g., academic, career satisfaction, mental and physical health) (17). A brief psychological intervention can help students cognitively reframe common academic challenges. STEM students who took part in an effective intervention had higher persistence and degree completion rates. Years after college, those students also had greater success and satisfaction in their careers (23).

LI background students often have additional responsibilities beyond their STEM education (i.e., full-time jobs, family obligations) that traditional students do not (62). Although additional activities effectively bolster a student's sense of belonging and improve their persistence rates, every professional development experience, cocurricular activity or research experience must be seen as crucial and compensated with either academic credit or a financial stipend.

Every S-STEM scholar can succeed. Every S-STEM program has its own resources and characteristics. As the literature and the programs report, every institution, be it a two-year rural MSI or a four-year city research school, can monitor its scholars' sense of belonging and enact an intervention to aid in their success.

KEY TAKEAWAYS

- Mentoring, research experiences, professional development activities, living-learning environments, interactive courses, and cognitive interventions are all empirically effective practices.
- No single practice is universally effective.
- LI background students are not less capable than their peers to succeed in STEM.
- LI background students have financial and time constraints.

A QUOTE FROM THE LITERATURE

"We found evidence to support the idea that a sense of belonging within a STEM discipline is not something immutable that students bring into classrooms, or that is inherent to STEM education and cannot be changed. Rather, it is malleable and shaped by contexts, interactions, and resources that are largely under the control of STEM departments. Concrete, yet simple, instructor and departmental practices, such as assessment policies, program design, group-work policies, and the provision of academic support, can positively influence students' sense of belonging and their commitment to persist in STEM majors" (10).

References

1. D. A. Totonchi, T. Perez, Y. Lee, K. A. Robinson, L. Linnenbrink-Garcia, The Role of Stereotype Threat in Ethnically Minoritized Students' Science Motivation: A Four-Year Longitudinal Study of Achievement and Persistence in STEM. *Contemp. Educ. Psychol.* **67**, 102015 (2021).

2. V. Tinto, From Retention to Persistence. *High. Ed* (2016), (available at https://www.insidehighered.com/views/2016/09/26/how-improve-student-persistence-and-completion-essay).

3. G. M. Walton, G. L. Cohen, A Question of Belonging: Race, Social Fit, and Achievement. *J. Pers. Soc. Psychol.* **92**, 82–96 (2007).

4. D. Wilson, D. Jones, F. Bocell, J. Crawford, M. J. Kim, N. Veilleux, T. Floyd-Smith, R. Bates, M. Plett, Belonging and Academic Engagement Among Undergraduate STEM Students: A Multi-institutional Study. *Res. High. Educ.* **56**, 750–776 (2015).

5. A. Vaccaro, B. M. Newman, Development of a Sense of Belonging for Privileged and Minoritized Students: An Emergent Model. *J. Coll. Stud. Dev.* **57**, 925–942 (2016).

6. J. L. Smith, K. L. Lewis, L. Hawthorne, S. D. Hodges, When Trying Hard Isn't Natural: Women's Belonging With and Motivation for Male-Dominated STEM Fields as a Function of Effort Expenditure Concerns. *Pers. Soc. Psychol. Bull.* **39**, 131–143 (2013).

7. J. L. Smith, E. Cech, A. Metz, M. Huntoon, C. Moyer, Giving Back or Giving Up: Native American Student Experiences in Science and Engineering. *Cultur. Divers. Ethnic Minor. Psychol.* **20**, 413–429 (2014).

8. L. R. M. Hausmann, J. W. Schofield, R. L. Woods, Sense of Belonging as a Predictor of Intentions to Persist Among African American and White First-Year College Students. *Res. High. Educ.* **48**, 803–839 (2007).

9. J. Engle, V. Tinto, "Moving Beyond Access: College Success for Low-Income, First-Generation Students" (Pell Institute for the Study of Opportunity in Higher Education, 2008), (available at https://eric.ed.gov/?id=ED504448).

10. E. Seymour, A.-B. Hunter, *Talking about Leaving Revisited Persistence, Relocation, and Loss in Undergraduate STEM Education* (Springer International Publishing, Cham, 1st ed. 2019).

11. N. M. Stephens, S. A. Fryberg, H. R. Markus, C. S. Johnson, R. Covarrubias, Unseen Disadvantage: How American Universities' Focus on Independence Undermines the Academic Performance of First-Generation College Students. *J. Pers. Soc. Psychol.* **102**, 1178–1197 (2012).

12. M. C. Jackson, G. Galvez, I. Landa, P. Buonora, D. B. Thoman, Science That Matters: The Importance of a Cultural Connection in Underrepresented Students' Science Pursuit. *CBE—Life Sci. Educ.* **15**, ar42 (2016).

13. T. L. Strayhorn, *College Students' Sense of Belonging: A Key to Educational Success for All Students* (Taylor and Francis, Milton, 2018).

14. S. Cheryan, V. C. Plaut, P. G. Davies, C. M. Steele, Ambient Belonging: How Stereotypical Cues Impact Gender Participation in Computer Science. *J. Pers. Soc. Psychol.* **97**, 1045–1060 (2009).

15. L. R. M. Hausmann, F. Ye, J. W. Schofield, R. L. Woods, Sense of Belonging and Persistence in White and African American First-Year Students. *Res. High. Educ.* **50**, 649–669 (2009).

16. M. J. Hansen, M. J. Palakal, L. White, The Importance of STEM Sense of Belonging and Academic Hope in Enhancing Persistence for Low-Income, Underrepresented STEM Students. *J. STEM Educ. Res.* (2023), doi:10.1007/s41979-023-00096-8.

17. G. M. Walton, G. L. Cohen, A Brief Social-Belonging Intervention Improves Academic and Health Outcomes of Minority Students. *Sci. Am. Assoc. Adv. Sci.* **331**, 1447–1451 (2011).

18. C. Good, A. Rattan, C. S. Dweck, Why Do Women Opt Out? Sense of Belonging and Women's Representation in Mathematics. *J. Pers. Soc. Psychol.* **102**, 700–717 (2012).

19. K. L. Lewis, J. G. Stout, N. D. Finkelstein, S. J. Pollock, A. Miyake, G. L. Cohen, T. A. Ito, Fitting in to Move Forward: Belonging, Gender, and Persistence in the Physical Sciences, Technology, Engineering, and Mathematics (pSTEM). *Psychol. Women Q.* **41**, 420–436 (2017).

20. T. A. Ito, E. McPherson, Factors Influencing High School Students' Interest in pSTEM. *Front. Psychol.* **9**, 1535–1535 (2018).

21. K. B. Kubala, Academic and Social Integration of Community College Students: A Case Study. Community Coll. *J. Res. Pract.* **24**, 567–576 (2000).

22. K. R. Rankin, S. G. Katsinas, D. E. Hardy, Community College Retention and Access Issues: A View from the Field. *J. Coll. Stud. Retent. Res. Theory Pract.* **12**, 211–223 (2010).

23. D. R. Means, K. B. Pyne, Finding My Way: Perceptions of Institutional Support and Belonging in Low-Income, First-Generation, First-Year College Students. *J. Coll. Stud. Dev.* **58**, 907–924 (2017).

24. S. T. Brady, G. L. Cohen, S. N. Jarvis, G. M. Walton, A brief social-belonging intervention in college improves adult outcomes for black Americans. *Sci. Adv.* **6**, eaay3689 (2020).

25. C. Peña, N. Ruedas-Gracia, J. R. Cohen, N. Tran, M. B. Stratton, Ten simple rules for successfully supporting first-generation/low-income (FLI) students in STEM. *PLoS Comput. Biol.* **18** (2022), doi:10.1371/journal.pcbi.1010499.

26. A. N. Google, G. Sekaya, Z. McMullen, J. A. Henning, Adopting a multi-systems approach: examining the academic belongingness of first-generation college students with multiple stigmatized identities in STEM. *Front. Educ.* **8** (2023) (available at https://www.frontiersin.org/articles/10.3389/feduc.2023.1183907).

27. Indiana University Center for Postsecondary Research, Carnegie Classifications 2021 public data file (2021), (available at http://carnegieclassifications.acenet.edu/downloads/CCIHE2021-PublicDataFile.xlsx *retrieved on 07/22/2023*).

28. S. Ahlqvist, B. London, L. Rosenthal, Unstable Identity Compatibility: How Gender Rejection Sensitivity Undermines the Success of Women in Science, Technology, Engineering, and Mathematics Fields. *Psychol. Sci.* **24**, 1644–1652 (2013).

29. J. Pearson, L. A. Giacumo, A. Farid, M. Sadegh, A Systematic Multiple Studies Review of Low-Income, First-Generation, and Underrepresented, STEM-Degree Support Programs: Emerging Evidence-Based Models and Recommendations. *Educ. Sci.* **12**, 333- (2022).

30. K. Kricorian, M. Seu, D. Lopez, E. Ureta, O. Equils, Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets. *Int. J. STEM Educ.* **7**, 1–9 (2020).

31. A. Byars-Winston, V. Y. Womack, A. R. Butz, R. McGee, S. C. Quinn, E. Utzerath, C. L. Saetermoe, S. Thomas, Pilot Study of an Intervention to Increase Cultural Awareness in Research Mentoring: Implications for Diversifying the Scientific Workforce. *J. Clin. Transl. Sci.* **2**, 86–94 (2018).

32. Z. S. Wilson, L. Holmes, K. deGravelles, M. R. Sylvain, L. Batiste, M. Johnson, S. Y. McGuire, S. S. Pang, I. M. Warner, Hierarchical Mentoring: A Transformative Strategy for Improving Diversity and Retention in Undergraduate STEM Disciplines. *J. Sci. Educ. Technol.* **21**, 148–156 (2012).

33. J. Handelsman, H. Handelsman, Wisconsin Program for Scientific Teaching, Howard Hughes Medical Institute Professors Program, Eds., *Entering mentoring: a seminar to train a new generation of scientists* (Board of Regents of the University of Wisconsin System, Madison, Wis., 2005).

34. D. S. Shelton, M. M. Delgado, E. V. G. Greenway, E. A. Hobson, A. C. R. Lackey, A. Medina-García, B. A. Reinke, P. A. Trillo, C. P. Wells, M. C. Horner-Devine, Expanding the landscape of opportunity: Professional societies support early-career researchers through community programming and peer coaching. *J. Comp. Psychol.* **135**, 439–449 (2021).

35. The Science of Effective Mentoring in STEMM | National Academies, (available at https://www.nationalacademies.org/our-work/the-science-of-effective-mentoring-in-stemm).

36. A. Byars-Winston, M. L. Dahlberg, Eds., *The Science of Effective Mentorship in STEMM* (National Academies Press, Washington, D.C., 2019; https://www.nap.edu/catalog/25568).

37. How a Mentorship Program Adapted and Built Connections to Last. *AAAS IUSE*, (available at https://aaas-iuse.org/resource/student-engagement).

38. G. Crisp, V. L. Baker, K. A. Griffin, L. G. Lunsford, M. J. Pifer, Mentoring Undergraduate Students: ASHE Higher Education Report. Volume **43**, Number 1 (2017).

39. W. B. Johnson, S. Long, D. G. Smith, K. A. Griffin, Creating a mentoring culture in graduate training programs. *Train. Educ. Prof. Psychol.* **17**, 63–70 (2023).

40. The Role of Soft Skills in STEM: Why Employers Are Looking Beyond Technical Proficiency | LinkedIn. *LinkedIn* (available at https://www.linkedin.com/pulse/role-soft-skills-stem-why-employers-looking-beyond-technical).

41. H. Karimi, A. Pina, Strategically Addressing the Soft Skills Gap Among STEM Undergraduates. *J. Res. STEM Educ.* **7**, 21–46 (2021).

42. D. Denecke, K. Feaster, K. Stone, *Professional Development: Shaping Effective Programs for STEM Graduate Students* (2017).

43. M. J. Chang, J. Sharkness, S. Hurtado, C. B. Newman, What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *J. Res. Sci. Teach.* **51**, 555–580 (2014).

44. A. Germuth, "Science, Technology and Math Preparation Scholarships (STAMPS) Summative Evaluation Report" (2022), p. 31.

45. M. C. Linn, E. Palmer, A. Baranger, E. Gerard, E. Stone, Undergraduate research experiences: Impacts and opportunities. *Science.* **347**, 1261757 (2015).

46. M. J. Graham, J. Frederick, A. Byars-Winston, A.-B. Hunter, J. Handelsman, Increasing Persistence of College Students in STEM. *Science.* **341**, 1455–1456 (2013).

47. *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads* (National Academies Press, Washington, D.C., 2011; http://www.nap.edu/catalog/12984).

48. National Academies of Sciences Engineering, Medicine, *Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities* (The National Academies Press, Washington, DC, 2017; https://nap.nationalacademies.org/catalog/24622/undergraduate-research-experiences-for-stem-students-successes-challenges-and-opportunities).

49. S. L. Eddy, K. A. Hogan, Getting Under the Hood: How and for Whom Does Increasing Course Structure Work? *CBE—Life Sci. Educ.* **13**, 453–468 (2014).

50. E. Etkina, K. Gibbons, B. L. Holton, G. K. Horton, Lessons learned: A case study of an integrated way of teaching introductory physics to at-risk students at Rutgers University. *Am. J. Phys.* **67**, 810–818 (1999).

51. R. J. Beichner, J. M. Saul, D. S. Abbott, J. J. Morse, R. J. Allain, S. W. Bonham, M. H. Dancy, J. S. Risley, The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project.

52. C. Velez, B. Nuechterlein, S. Connors, G. RedShirt Tyon, T. M. Roane, D. C. Mays, Application of the Indigenous evaluation framework to a university certificate program for building cultural awareness in science, technology, engineering, and mathematics. *Eval. Program Plann.* **92**, 102066 (2022).

53. S. Sandrone, G. Scott, W. J. Anderson, K. Musunuru, Active learning-based STEM education for in-person and online learning. *Cell.* **184**, 1409–1414 (2021).

54. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, M. P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci.* **111**, 8410–8415 (2014).

55. J. L. Zimmerman, The Meyerhoff Scholarship Program at UMBC - Analyzing the Elements of Success. *FASEB J.* **21**, A40–A40 (2007).

56. M. R. Sto. Domingo, S. Sharp, A. Freeman, T. Freeman, K. Harmon, M. Wiggs, V. Sathy, A. T. Panter, L. Oseguera, S. Sun, M. E. Williams, J. Templeton, C. L. Folt, E. J. Barron, F. A. Hrabowski, K. I. Maton, M. Crimmins, C. R. Fisher, M. F. Summers, Replicating Meyerhoff for inclusive excellence in STEM. *Science.* **364**, 335–337 (2019).

57. D. R. Johnson, Examining Sense of Belonging and Campus Racial Diversity Experiences Among Women of Color in Stem Living-Learning Programs. *J. Women Minor. Sci. Eng.* **17**, 209–223 (2011).

58. M. L. A. Stassen, Student Outcomes: The Impact of Varying Living-Learning Community Models. *Res. High. Educ.* **44**, 581–613 (2003).

59. K. R. Schneider, A. Bickel, A. Morrison-Shetlar, Planning and Implementing a Comprehensive Student-Centered Research Program for First-Year STEM Undergraduates. *J. Coll. Sci. Teach.* **44**, 37–43 (2015).

60. A. Rattan, K. Savani, D. Chugh, C. S. Dweck, Leveraging Mindsets to Promote Academic Achievement: Policy Recommendations. *Perspect. Psychol. Sci.* **10**, 721–726 (2015).

61. A. M. Kelly, Social cognitive perspective of gender disparities in undergraduate physics. *Phys. Rev. Phys. Educ. Res.* **12**, 020116 (2016).

62. J. M. Ostrove, S. M. Long, Social Class and Belonging: Implications for College Adjustment. *Rev. High. Educ.* **30**, 363–389 (2007).

Acknowledgments

We would like to acknowledge the S-STEM programs, including their Principal Investigators, Co- Principal Investigators, evaluators, and project staff who contributed to this deep dive report.

Benjamin Franklin Institute of Technology. 2130159. *Support for Electrical Engineering Students Emphasizing Pathways to the Electric Power Sector*

Boise State University. 1930464. *Scholarships and Supports to Increase Access to and Completion of Masters Degrees in Engineering*: https://www.boisestate.edu/coen-ce/graduate-students/sens-gps

Chandler-Gilbert Community College. 2220959. *Scholarships, Mentoring, and Professional Support to Improve Engineering & Artificial Intelligence Student Success at Community Colleges*: cgc.edu/reach

Coe College. 1742326. *The STEMPath Approach: Success for Low Income Students*

College of Mount Saint Vincent. 1833610. *Using a Scientific Literacy Approach to Increase Retention and Graduation of Undergraduates in Biology, Biochemistry, and Chemistry*

College of Southern Maryland. 1833559. *Scholarships and Support Services to Increase Student Success in STEM*: https://www.csmd.edu/costs-aid/scholarships-financial-aid/scholarships/stem-scholars.html

College of the Canyons. 2130457. *Improving Educational Outcomes at Two-Year Colleges through Mentorship, Support Services, and Equitable Classroom Practices*: https://www.canyons.edu/administration/ie2/equity/alliances/stemequityalliance/s-stem-scholars.php

Colorado State University-Fort Collins. 1930150. *Scholarships and Learning Community to Build Academic Momentum in STEM Students who Transfer from a Community College to a Four Year University*: https://w2r.colostate.edu/w2r-nsf-scholars

Columbus State Community College. 2130235. *Future Tech Scholars: An Information Systems Technology Scholarship Program*: www.cscc.edu

Community College of Baltimore County. 1833839. *Math Acceleration for STEM Students*

CUNY Hostos Community College. 2221234. *Increasing the Access and Success of Scholars in Mathematics and Computer Science at a Hispanic Serving Institution*: https://www.hostos.cuny.edu/Administrative-Offices/Office-of-Academic-Affairs/Departments/Mathematics/MACSS-Program

Denison University. 2030762. *Multilevel Mentoring to Improve Belonging, Metacognition, and Science Identity of Bachelor Degree-Seeking Science and Mathematics Students*

Earlham College. 2220647. *Increasing Success of STEM Students through Cohort Building, Mentoring, and Career Discerning Experiences: an Interdisciplinary Collaboration*: https://earlham.edu/cost-affordability/types-of-aid/scholarships/earlham-science-scholar-program

East Stroudsburg University of Pennsylvania. 1564634. *Clear Path - Bachelor's Degree Completion Scholarships*

Felician University. 1930141. *Science and Information Technology Scholars: Recruiting, Retaining, and Graduating Biology, Computer Science, and Cybersecurity Students to Meet Workforce Needs*

Furman University. 2030650. *Scholarships and Science Opportunities, Activities, and Research to Support Undergraduate STEM Student Success*

Grand Valley State University. 1742463. *Retaining and Inspiring students in Science and Engineering (RISE)*: www.gvsu.edu/rise

Grand Valley State University. 2030615. *Scholarships for Student Success in a Combined Bachelor/Master Degree Program in Engineering*

Illinois Wesleyan University. 1742224. *A Community Assets Program that Fosters the Next Generation of STEM Leaders*: www.nexstem.org

Indiana Wesleyan University-Marion. 2130078. *Connecting Science Identity to STEM Success at a Rural Primarily Undergraduate Institution Propelled by an Evidence-Based First Year Experience*

Keene State College. 2030621. *Early Research Experiences and Mentoring to Increase the Numbers of Biology and Chemistry Graduates Prepared for Careers in Science*: https://www.keene.edu/featured/steps

Landmark College. 2129912. *Access to Innovative Education: Providing Learning Opportunities and Scholarships for Neurodivergent Students in STEM*: https://www.landmark.edu/admissions/tuition-and-financial-aid/grants-scholarships/aie-stem-scholarship-program

Louisiana Tech University. 2221638. *S-STEM SUCCESS: Supporting Undergraduates through Curricular and Co-Curricula Engagement and Student Scholarships*

Marquette University. 1565099. *COSMIC: Change Opportunity - Start Masters in Computing*

McHenry County College. 1742147. *MCC STEM Scholarship Program*

Michigan State University. 1643723. *Supporting Excellent Engineers (SEE)*: https://www.egr.msu.edu/seescholars

Michigan State University. 1643833. *Careers in Food, Energy, and the Environment - an Interdisciplinary Approach*: https://msustemfee.com

Mt Hood Community College. 2030632. *Scholarships, Strategic Course Sequencing, and Comprehensive Student Support to Increase Undergraduate Degree Completion in Computing and Cybersecurity*

Naugatuck Valley Community College. 1833974. *Naugatuck Valley's STEM Inclusive Opportunity Network*: nv.edu/nvision

New Mexico State University-Main Campus. 1833630. *Preparing Highly Qualified Students with Financial Need for Careers in Computing and Cyber-Security through Evidence-Based Educational Practices*

North Carolina A&T State University. 1930387. *Preparing Academically Talented Students with Financial Need to be the Next Generation of Engineering Professionals by Fostering Innovation and Leadership Skills*

North Carolina State University at Raleigh. 1643814. *Interdisciplinary Biochemistry Graduate Program*: https://ibmp.wordpress.ncsu.edu

Northern Illinois University. 1834076. *Scholarships and Enhanced Mentoring to Support Graduation of Students in Science and Mathematics*: https://www.niu.edu/clas/research/belong-project.shtml

Norwich University. 1930263. *Promoting Success of Undergraduate STEM Students Through Scholarships, Mentoring, and Curricular Improvements in First-year Mathematics Courses*

Ohio Northern University. 2221138. *Maximizing Success of Low-Income Students through Personal Relationships and Evidence-Based Instructional Experiences*

Pittsburgh Technical College. 2030741. *Financial and Programmatic Supports to Prepare Undergraduates for Work in Technology Fields*: https://ptcollege.edu/financial-aid/sstem-scholarship

Portland State University. 1742542. *Reducing Transfer Shock: Developing Community and Collaborations to Support Urban STEM Transfer Students*

Potomac State College of West Virginia University. 1644119. *Statler Increasing Access and Diversity in Engineering Program (ADE)*: https://fep.statler.wvu.edu/academics/aces-academy-of-engineering-success

Rowan University. 2221511. *Engineering Persistence: A Support System for Low Income Students to Catalyze Diversity and Success*

Saint Cloud State University. 1742517. *Academic Collaboration and Coordination model to Ensure Student Success in STEM (ACCESS STEM): A Partnership to Improve Recruitment, Retention, and Student Success*: https://www.stcloudstate.edu/cose/resources/scholarships/access-stem.aspx

Saint John Fisher University. 1833904. *Community Research and Cognitive Reframing for a Community Retained in Science*

Savannah State University. 1930371. *Supporting Undergraduate STEM Degree Completion Through a Learning Community/ Cohort Model that Develops Belonging, Mindset, and Purpose*

South Mountain Community College. 2030105. *Intensive Student Supports to Increase Persistence and Completion of STEM Associate Degrees*

Southern Connecticut State University. 2221225. *Preparing Computational Biologists for the New England Workforce*: https://www.southernct.edu/combine

Spokane Falls Community College. 1741960. *Spokane Falls Community College Engineering Scholarship Project*

St Olaf College. 1930235. *Experiences in Metacognition and Early Research to Increase Degree Completion of STEM Undergraduate Students*

Stony Brook University. 1643671. *Academic and Social STEM Excellence for Transfer Students (ASSETS)*

Suffolk County Community College. 2221392. *Improved Support for Undergraduates at Community College Engaged in STEM Studies*

Texas A&M University-San Antonio. 2031497. *Creating Educational Pathways and Cultivating Leadership at a Hispanic-Serving Regional University to Prepare Undergraduates for STEM Careers in Water Science and Technology Fields*

The Pennsylvania State University. 2130022. *Leveraging Innovation and Optimizing Nurturing in STEM: The LION STEM Scholars Program*: https://sites.psu.edu/berkslionstemprogram

The University of Texas at El Paso. 1930558. *Pathways to Success in Graduate Engineering: Understanding and Supporting the Critical Transition from Undergraduate to Graduate Engineering Studies*: https://www.utep.edu/engineering/passe

The University of Texas at San Antonio. 1741954. *Supporting Student Success and Increasing Diversity in Computer Science*: http://www.cs.utsa.edu/~korkmaz/i-focus-cs/index.html

The University of Texas Rio Grande Valley. 2130512. *Developing an Inclusive National Model to Support the Success of Low-Income Graduate Students in STEM*: https://www.utrgv.edu/stem

Truman State University. 1742289. *A Scaffolded Learning Community to Increase Self-Efficacy and Persistence in STEM*

University of Alaska Anchorage. 2030114. *Increasing the Academic and Career Success of Alaska Native and Rural Students in Science and Math*

University of Arizona. 1742324. *Supporting Success of Science Transfer Students*

University of Arizona. 1930455. *Bridging Faculty and Student Cultures: Culturally Responsive Support for STEM Students Transferring between Two- and Four-Year Hispanic Serving Institutions*: https://stembridge.arizona.edu

University of Hawaii Maui College. 2030979. *Uniting Culture, Purpose, Connection, and the Academic Journey to Advance Hawaii's Low-Income Undergraduate Students in STEM*

University of Houston. 1644191. *STEM Scholarship Program with Promotion and Retention of STEM Education through Networking Team (PARENT) Support*: https://uh.edu/nsm/students/scholarships/stem-scholarship-program

University of Idaho. 1458685. *Career Launch in Engineering Scholarship Program (Career Launch)*

University of Massachusetts-Dartmouth. 2030552. *Implementation of a Contextualized Computing Pedagogy in STEM Core Courses and Its Impact on Undergraduate Student Academic Success, Retention, and Graduation*: https://accomplish.sites.umassd.edu/program-overview

University of Massachusetts-Dartmouth. 2130252. *Scholarships to Accelerate Engineering Leadership and Identity in Graduate Students*

University of Michigan-Dearborn. 2130058. *Retaining Students in STEM on a Commuter Campus with Efficient High Impact Practices*

University of Nebraska-Lincoln. 1930211. *Educating Undergraduate Students for STEM Career Opportunities in Nebraska: Networks, Experiential-learning, & Computational Thinking*: https://scimath.unl.edu/stem-connect

University of Nevada-Reno. 1833738. *Creating Retention and Engagement for Academically Talented Engineers*: https://www.unr.edu/engineering/student-resources/scholarships/create

University of North Carolina at Greensboro. 2029883. *Preparing College Students Who Enter from High School or Transfer from Community Colleges for STEM Careers and Graduate School*: https://stamps.uncg.edu

University of North Carolina at Pembroke. 1930539. *Expanding Career Pathways for Academically Talented Biology and Chemistry Undergraduates by Combining Financial Support with High-Impact Co-curricular Services*: https://www.uncp.edu/departments/biology/compass-scholarship-program

University of Washington Tacoma Campus. 1741595. *Achieving Change in our Communities for Equity and Student Success (ACCESS) in STEM*: https://www.tacoma.uw.edu/sias/sam/access-stem-program

University of West Alabama. 2128109. *Biology Opportunities and Scholarships for Success II*

University of Wisconsin-Stevens Point. 2220586. *Supporting Low-Income Students Studying Biology, Chemistry, and Biochemistry from First Year to Graduation in Rural Wisconsin*: https://www.uwsp.edu/admissions-aid/s-stem-scholars-program

Utica University. 2030447. *Pathways to Achieving STEM Success: Scholarships, Mentoring, and Development of STEM Identify to Support Undergraduate STEM Degree Completion*