STEM STUDENTS & THEIR SENSE OF BELONGING:
S-STEM PROGRAMS’ PRACTICES & EMPIRICALLY BASED RECOMMENDATIONS

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
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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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, students’ sense of belonging may be reflected in 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 belongingness is predictive of their success and performance, and their persisting 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.

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. 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.

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).

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.”

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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)

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**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 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 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.
### S-STEM Strategies to Develop Sense of Belonging

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<thead>
<tr>
<th>Activity</th>
<th>Utilized (%)</th>
<th>Not Utilized (%)</th>
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<tbody>
<tr>
<td>Faculty Mentoring</td>
<td>96%</td>
<td>4%</td>
</tr>
<tr>
<td>Academic Advising</td>
<td>84%</td>
<td>16%</td>
</tr>
<tr>
<td>Cohort Experiences</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>Professional Development</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Peer Mentoring</td>
<td>68%</td>
<td>32%</td>
</tr>
<tr>
<td>Research Experiences</td>
<td>63%</td>
<td>37%</td>
</tr>
<tr>
<td>Course Instructional Style</td>
<td>47%</td>
<td>53%</td>
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### 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. S-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 improve 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).

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 (30). 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 mentor-mentee matching can help the students form a stronger community.

### 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.”**

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

**“We are rewapping 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.”**

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

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

- 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)
- 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).
Learning science makes my life more meaningful.


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Benjamin Franklin Institute of Technology, 2130059. 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


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.csccc.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/stem


Louisiana Tech University, 2221638. S-STEM SUCCESS: Supporting Undergraduates through Curricular and Co-Curricular 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.engr.msu.edu/see/scholars


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/mvision

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://bmbp.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


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


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

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

The University of Texas Rio Grande Valley, 2130512. Increasing the Academic and Career Success of Alaska Native and Rural Students in Science and Math

The 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 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