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An NSF-LSAMP Model for the Successful Transition of Underrepresented Students into STEM Majors and Beyond

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Bugallo is a senior member of the IEEE, serves on several of its technical committees and is the current vice chair of the IEEE Signal Processing Society Signal Processing Theory and Methods Technical Committee and the chair of the EURASIP Special Area Team on Theoretical and Methodological Trends in Signal Processing as well as an elected member of the IEEE Signal Processing Society Sensor Array and Multichannel Technical Committee. She has been part of the technical committee and has organized various professional conferences and workshops. She has received several prestigious research and education awards including the State University of New York (SUNY) Chancellor's Award for Excellence in Teaching (2017), the 2019 Ada Byron Award of the Galician Society of Computer Engineers (Spain) for a successful professional career path that inspires women to engineering study and careers, the Best Paper Award in the IEEE Signal Processing Magazine 2007 as coauthor of a paper entitled Particle Filtering, the IEEE Outstanding Young Engineer Award (2009), for development and application of computational methods for sequential signal processing, the IEEE Athanasios Papoulis Award (2011), for innovative educational outreach that has inspired high school students and college level women to study engineering, the Higher Education Resource Services (HERS) Clare Boothe Luce (CBL) Scholarship Award (2017), and the Chair of Excellence by the Universidad Carlos III de Madrid-Banco de Santander (Spain) (2012).

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With over 25 years of experience in both the research and teaching communities on Long Island, Dr. Candice J. Foley endeavors to bring her perspectives of each of these realms to her STEM students at Suffolk County Community College. As the Principal Investigator for Suffolk County Community College's three consecutive National Science Foundation S STEM scholarship grants, the the National Institute of Health IRACDA grant (Institutional Research and Career Development Award), the NSF LSAMP, the NSF SENCER/NYP, and Long Island Community Foundation "Removing Barriers and Strengthening STEM capacity at Suffolk County Community College" grants, Dr. Foley served as the STEM Coordinator for all SCCC NSF STEM Scholars on three campuses. Dr. Foley has also served on national grant projects involving curricular reform for chemistry education. Her experiences at the State University of New York at Stony Brook, Suffolk County Community College, and Brookhaven National Laboratory has enabled her to focus upon the adaptation and implementation of innovations in classroom learning and undergraduate research through curricular innovation and technology based software for the community college application. Dr. Foley is a delegate to the SUNY Research Foundation Undergraduate Research Steering Committee, the Empire State STEM Education Initiative as well as the Interim Associate Dean for Curriculum Development.

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The SUNY LSAMP Model for Successful Transition of Underrepresented Students into STEM Majors and Beyond

Abstract

The underrepresentation of students in STEM disciplines has been a consistent issue for traditionally marginalized students in higher education. Institutions have fostered innovative programs and implemented policies to mitigate the challenges that historically underrepresented students consistently encounter persisting in STEM. Since 1996, the SUNY LSAMP Alliance, which consists of 14 universities, colleges and community colleges, has been an active program committed to assist students in closing the gaps.

As an Alliance, the program has provided comprehensive social and academic support for overcoming obstacles that historically underrepresented STEM students face. Measures comprise the execution of interventions for the difficult transitions for students and include social and academic integration strategies for the two-year to four-year transition; socialization into science through experiential learning, including domestic and international research programs and experiences; and improving STEM pedagogy and curriculum to advance systematic change for historically underrepresented students. In addition to the development of interventions, a longitudinal research study explores the mechanisms that are bridges or barriers for historically underrepresented STEM students and how these pathways translate to their STEM identity.

The SUNY LSAMP Alliance has positioned itself to be a leader in STEM advocacy and advancement of historically underrepresented scholars. The Alliance has seen an exponential increase in enrollment of underrepresented students with a 1013% increase since its inception. Graduation rates have also exhibited a significant increase. From the first year of the program in 1996, to its current year in 2020, there has been a yearly increase of 710% for bachelor's degrees, 1530% for masters degrees and 1500% for doctoral degrees.

The United States has been fully aware of the subversive issue of maintaining underrepresented students (African American, Hispanic, Latinx, Alaskan Natives, and American Indian students) in Science, Technology, Engineering and Mathematics (STEM) majors. Even with massive interventions, the underrepresented students have not experienced exceptional gains [12].

The State University of New York Louis Stokes Alliance for Minority Participation (SUNY LSAMP), has been a National Science Foundation funded program since 1996. SUNY LSAMP spans across 400 miles and serves many New York state doctoral granting institutions, small liberal arts institutions, and community colleges. At its core, SUNY LSAMP objectives include: a) curricular and pedagogical innovations in STEM education; b) development of an innovative, cognitive, and social support network; c) development of experiential learning that leads to research and practice in undergraduate and graduate students; and d) scholarship and research about STEM Education.

Since its inception, SUNY LSAMP has collaborated with many institutions, with Stony Brook University as the university center. SUNY LSAMP has been very successful in its mission. Together the Alliance has researched and attempted to alleviate and mitigate ongoing problems for underrepresented students in STEM. The Alliance has offered innovative programs and developed powerful ideas to assist in the progress of its students. Faculty and staff have become advocates for best practices at local and state levels.

The SUNY LSAMP Research Grant reported that the Alliance was effective through many facets of the project including continuity and the delivery of resources. Leveraging other strong programs, including Scholarships in Science, Technology, Engineering and Math (S-STEM), Collegiate Science and Technology Entry Program (CSTEP), Science and Technology Entry Program (STEP), and Equal Opportunity Program (EOP), has been a valuable and beneficial enterprise. In addition, the LSAMP program has effectively achieved long-term goals that continually evolve to meet the needs of the students. Lastly, the delivery of resources has included many programs which assist with the transition environment for LSAMP students [13].

Implemented measures

The SUNY LSAMP Alliance has built upon the work from each previous phase of the program. Within each phase, the SUNY LSAMP program has adjusted and advanced in a positive direction and SUNY LSAMP institutions have evaluated their programs to fit the needs of their students. All phases build on the successful outcomes of the previous phase. Each phase continues to develop the infrastructure and processes of the Alliance. In addition, each phase addresses the challenges of the preceding phase and adapts to create positive change.

Phase I (1996-2001) built the Alliance infrastructure and launched primary activities, and initial programs. Phase I was to establish the Alliance and to form collaboration among campuses and LSAMP Students. Phase II (2001-2006) advanced the programs and increased and diversified activities. This phase looked to propel minority enrollment and degree production. In addition, this phase initiated workforce preparation and preparing for graduate school entrance. Phase III

(2006-2011) enhanced students' advancement through the STEM majors and focused on STEM graduate programs. This phase continued to improve the retention and attrition of underrepresented students during critical transitions. Phase IV (2011-2016) focused on improving STEM pathways, and preparing global scholars. This phase further enhanced the success of students at critical transition points, such as 2-year to 4-year, undergraduate to graduate, and into the workforce. This phase developed access to international research experiences for underrepresented students by providing integrated academic and socialization experiences. Phase V (2016-2021), the most recent phase, has focused on the grand challenges that face underrepresented students in the first two years and their socialization into science. Comprehensive support services were expanded that focused on the grand challenges, such as math skills. This phase also provided experiential STEM learning experience in the way of research, international research, and internship to assist the students along the STEM pathway.

The first goal of Phase V has been to prepare underrepresented students for the successful transition into STEM majors, and incorporates four vital domains. The first domain is to provide comprehensive social and academic support for the first two years of a student's academic tenure. Math preparedness has been determined as a primary obstacle for the retention and a contributory factor for the attrition for underrepresented students in STEM majors [1], [5], [25] [14], [6]. Research indicates that comprehensive programs stressing academic and social integration have been an effective intervention to assist underrepresented students in their first two-years [24], [9], [13], and for community college students [3], [4], [20], in their transition to four-year schools. The second domain is to increase preparation for transfer students at both two-year and four-year alliance institutions. The third and fourth domains are to identify and utilize the research findings from the SUNY LSAMP Research Project (The FIT Model of STEM Success-described below) research component of the LSAMP program to optimize success of underrepresented STEM students and community college STEM transfer students.

The second goal of Phase V was to increase socialization in STEM by providing experiential learning and this goal had three vital domains. The first domain includes providing domestic and international research opportunities for students. Research studies have substantiated that early access and opportunity for undergraduate student research experiences have increased success in STEM programs and lowers barriers for transition to graduate school [13]. The second domain is to increase students' STEM professional skills and experience. Researchers have noted that socialization opportunities have been shown to be crucial to underrepresented student success [9], [7], [10], [18]. The last domain is to scaffold students' preparedness for timely success in transitioning into STEM graduate programs. Gafney [13] has noted that programs, such as undergraduate research, summer bridge programs, seminars, and conferences have been inspirational and motivating factors for underrepresented students to pursue graduate school opportunities.

The third and final goal of Phase V is to promote systematic changes for the advancement of LSAMP students. This goal incorporates the dissemination of best practices which continue the upward trajectory of opportunities for LSAMP students. LSAMP campuses will advocate for continued funding for students after the project ends, as well as to refine and improve STEM pedagogy and curriculum.

Best practices

Evaluation reports have researched and highlighted what practices and support services were instrumental for student success of LSAMP scholars. Many activities were implemented and became a successful measure for guidance and support increased successful outcomes. In order to develop and create supportive networks for the academic and social needs for our students, all of the practices implemented through the alliance addressed: (1) formal academic support, (2) informal academic support, and (3) social network access.

Socialization in STEM was an impactful initiative for the Alliance and included diverse and varied opportunities for undergraduate research experiences. Research placements were shown to have fostered a sense of scholarly achievement and innovation. Additionally, research preparation skills, including research methods courses, presentation skills, abstract and research proposal writing, and grant proposal seminars were incorporated. LSAMP scholars were mentored and supported for opportunities to attend and to present their research, via poster or oral presentations, at conferences in local and national arenas.

Many SUNY LSAMP Alliance institutions conducted *Summer Research Institutes*. These programs were carefully planned to include both pre-freshman and undergraduates. The undergraduate programs had a duration of six to ten weeks. These included research placements and a variety of professional training, graduate school preparation, training for research, community building and service activities. In addition, *Pre-Freshman Programs* were also developed. These one to five week programs introduced pre-freshman students to the campus, prepared them for key STEM gatekeeper courses, provided hands-on STEM experiences, community building and skills building activities, and preparation for research.

During the academic year, a multitude of math programs were provided. *Math fortification* programs were incorporated into academics of the students. *STEM Prep* camps were administered for incoming first year students for supplemental calculus and precalculus courses. In addition, math programs were devised for the time period after mid-terms.
International research placements have been an area of focus for the SUNY LSAMP program. As research has shown, study abroad opportunities provide important experiences for underrepresented students, especially for increased entrance into STEM Ph.D. programs [19]. LSAMP students have participated in research in many countries, including Madagascar, Paris, Turkey, Germany, Spain, Costa Rica, China and Korea.

Community college and transfer students were the prime focus of Phase V. This phase increased the breadth of activities for this demographic of students. Activities that were introduced included transfer workshops, *Transfer Social Hour*, laboratory tours, *Panel of Transfer Experts,* and *Culture of Science* course. In addition, Alliance institutions evaluated and modified articulation agreements between two-year and four-year institutions to ameliorate obstacles of transition for transfer students. In addition, LSAMP aligned with other programs that served underrepresented STEM students, such as S-STEM ASSETS (Scholarships in STEM: Academic and Social STEM Excellence for Transfer Students).

Mentoring has been vital for the success of LSAMP students and has been incorporated in a variety of program capacities. Mentoring for first-year students were programs that harnessed upper class students to mentor first year students. In addition, first year students were paired with volunteer faculty mentors. Other mentoring programs, such as Peer mentoring programs, *Junior-Senior Connect*, and STEM faculty roundtables were formed to provide mentoring for all LSAMP students.

Academic support programs also focused on the mental health of LSAMP students. An average of 35% college students experienced some form of mental health issue [2]. According to Clark and Mitchell [8, pg. 67], "minority stress suggests that students of color experience cognitive stressors specific to their racial identity or status as minorities on campus". Programs incorporated for underrepresented students included *Stress Management for Finals* workshops, *Staying Healthy and Managing Everyday Stress*, and getting involved on campus. In addition, students were provided with methods to increase financial literacy, such as *Debt Managemen*t workshops, *Money Management for College Students*, and the *Everyday Guide to Taxes.* Encouraging and preparing students for transition to graduate school is a main priority for SUNY LSAMP. The Alliance has documented significant numbers of students who complete the STEM pathway and achieve PhD's. SUNY LSAMP has worked closely with NSF SUNY Alliance for Graduate Education and the Professoriate (SUNY AGEP) and Bridge to the Doctorate to promote, retain, and advance underrepresented students in STEM graduate study. It is through partnerships and collaborations within these programs that LSAMP programmatic activities were developed including first generation interventions, graduate school preparation workshops, grant proposal workshops, and shadowing programs.

Professional preparation and development was a consistent programmatic component for LSAMP students through the students' academic tenure. Programs developed for career application skills included *How to Interview*, *Resume and Cover Letter* workshops, and *Dress for Success* for interviews. In addition, networking skills development workshops were incorporated including *Networking with a Purpose, Networking and Etiquette* dinners, *Professional Networking* workshops, *Leveraging Your Networks*, and public speaking workshops.

Student outcomes

The SUNY LSAMP Alliance has substantially increased the numbers, preparation, development and outcomes for underrepresented students in STEM. LSAMP has successfully enrolled 151,779 undergraduate students in STEM majors, with a steady increase each academic year (Figure 1). As a broader impact the SUNY LSAMP Alliance has produced a total of 16,044 students graduate with a bachelor's degree (Figure 2), 1,807 students graduate with a masters degree (Figure 3), and 376 graduate with a doctoral degree (Figure 4).

The SUNY Alliance has seen exponential growth since 1996. In the first cycle year (1996-1997), 220 bachelors, 13 masters and 2 doctoral degrees were awarded. By comparison, in the most recent cycle year (2019-2020), 2,010 bachelors, 233 masters and 34 doctoral degrees were awarded (Figures 1-4).

In 2019-2020, 22,320 bachelor degrees were awarded in the SUNY LSAMP campuses. Out of those degrees, 8,265 degrees awarded were STEM degrees, with 2,010 earned by underrepresented students. SUNY LSAMP has achieved increased advancement for specific STEM majors that have traditionally included fewer underrepresented students. For instance, yearly computer and information science bachelors degrees increased 629% (N=2296) from 1997 to 2019. When further analyzed, female yearly degrees increased 583% (N=459) from 1997 to 2019.

Figure 1

UREP Enrollment for SUNY LSAMP Scholars

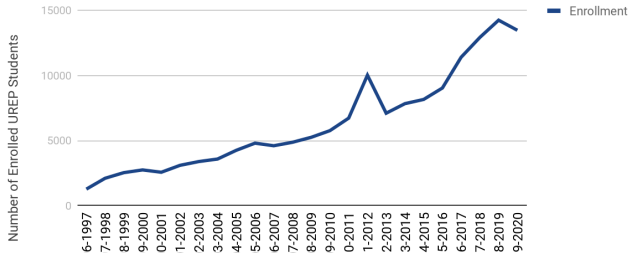


Figure 2

Bachelors Degrees Awarded to SUNY LSAMP Scholars

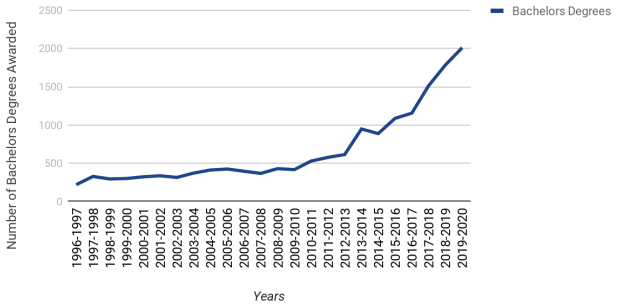
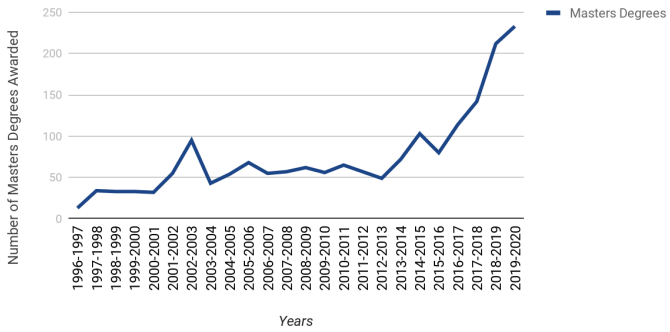
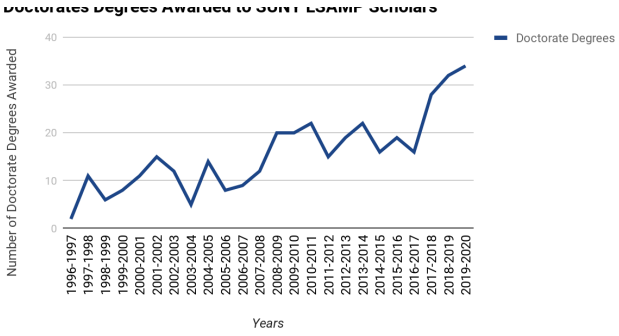


Figure 3

Masters Degrees Awarded to SUNY LSAMP Scholars





FIT Model of STEM success

The research outlined in this project leverages the conceptual and methodological expertise of the research team in studying processes of educational engagement, academic and life transitions, and historically underrepresented (UREP) student groups in STEM fields through a novel and comprehensive multi-institution, repeated measures longitudinal research study. Building on our own and others' research and theoretical frameworks on educational engagement of students in STEM domains, we focus on exploring the mechanisms that serve as either barriers or bridges to STEM success among UREP students (relative to non-UREP students) during the transition into and through the early stages of students' collegiate careers. Given the critical mass of UREP students who begin their STEM education and experiences at community colleges, these three transition points represent critical pathways that ultimately fed the STEM pipeline. A systematic, theory-driven, longitudinal assessment of these multiple pathways simultaneously is essential for identifying how, when and why UREP students persist in STEM education over time. Although there have been informal and formal evaluations of the LSAMP Alliance, such as obtaining feedback from students who attend workshops and seminars, there

has yet to be a theory-driven, rigorous empirical test of the effectiveness of the LSAMP Alliance in promoting student success from community colleges to four-year institutions and the workforce. The proposed multi-institution research project builds on the long-standing LSAMP Alliance structure and utilizes the Research Team's theoretically grounded model - *Fostering (STEM) Identity through Transitions (FIT) Model* – to explore issues of STEM success.

The **FIT Model of STEM success** theorizes that a strong and stable **STEM Identity** is critical for sustained interest and achievement in STEM fields, and that such a STEM Identity is created and maintained by experiences of: (1) STEM academic-efficacy, (2) sense of belonging with peers and the University, and (3) mentors and role models of STEM success [11], [15], [17], [22], [23]. Consistent with the FIT Model, STEM enrichment programs like SUNY LSAMP Alliance are expected to promote STEM Identity among UREP students through workshops, training, mentoring and enrichment experiences that contribute to student efficacy, belonging, and mentorship. Further, the FIT Model suggests that developing and maintaining a strong STEM Identity is particularly critical during transitions when most students (including UREP students) struggle to adjust to a changing academic culture and environment [17].

The Research Team's (Dr. Bonita London and Dr. Sheri Levy) funded, published, empirical research to date provides foundational support for the importance of the components and structure of the FIT Model in predicting STEM Success Outcome**s** such as STEM grades, STEM extracurricular participation (e.g., research involvement), persistence in STEM major, and sustained interest in STEM career objectives [16], [22], [23]. Our collaborative work has been funded by three NSF research grants across 9 years (2007 – present, as PI and Co-PI) in which we designed, implemented, published and disseminated empirical research from a comprehensive six-year longitudinal, time course study of the psychosocial factors that predict sustained STEM engagement of undergraduate and graduate STEM students (particularly women) in four-year and graduate STEM degree programs. We are currently conducting a rigorous study to directly test whether UREP students' exposure to STEM enrichment programs (e.g., LSAMP/CSTEP) impacts STEM Identity and STEM success outcomes over and above UREP students' exposure to general enrichment programs (e.g., EOP), and both UREP and majority group members with no access to any type of enrichment program at one 4-year college.

Focusing on testing the FIT model, data from over 700 entering first year undergraduate students, and over 300 students over five timepoints of data (through students' second year of college), Kim, London and colleagues (in preparation) explored the pathways to STEM achievement. Using structural equation modeling, Kim, London and colleagues found that students' interest in STEM predicted their perceived identity compatibility (PIC: defined as the sense that their self-concept is closely aligned with their STEM career). PIC is a core concept of identity research, emphasizing that when individuals perceive a close connection between their self-concept and their career goals, they are more likely to maintain motivation, interest and persist in that domain, even when they experience difficulty [22]. Further, the data suggest that PIC leads to higher sense of belonging to the University and it's members. Kim, London and colleagues also demonstrate that interest in a STEM career and sense of belonging in one's University both predicted STEM self-efficacy among students (confidence in one's ability to manage STEM academic tasks). STEM self-efficacy in turn predicted higher STEM achievement in classes through students' second year of college. These findings highlight the importance of

the core psychosocial constructs (interest, identity, belonging and efficacy) in predicting STEM achievement for all students. While these pathways are essential for all STEM students to achieve success, UREP students often report lower sense of belonging and lower identity compatibility with STEM than their peers. Given that these constructs are important for STEM achievement, it is particular important to bolster UREP students by addressing issues of belonging and efficacy.

In another model drawn from the LSAMP FIT data, Bermejo, London and colleagues (in preparation) found critical links between reports of discrimination from underrepresented undergraduate students, and higher rates of stress, anxiety and depression (increase rates for UREP students compared to their peers over the five timespoints of data). The strain on UREP students' well-being due to experiences of marginalization and threat is another critical concern that should be addressed through institutional level interventions. The data further shows that while distress for UREP students increases over time, feelings of STEM belonging mitigate the impact of discrimination on distress. Drawing together findings that STEM belonging is a critical factor in predicting efficacy and ultimately achievement, and also findings that STEM belonging can mitigate stress responses for UREP students, it is particularly important to identify both the factors that undermine STEM belonging within an institution and the factors that enhance STEM belonging.

Conclusion

The underrepresentation of traditionally marginalized students in STEM has been a continuous concern for higher education. The SUNY LSAMP Alliance has recognized the challenges that are persistent to underrepresented students in STEM. The Alliance has initiated, incorporated, and utilized programs, activities and interventions to address and assist with these challenges. By creating comprehensive social and academic support for overcoming obstacles that historically underrepresented STEM students face, the SUNY LSAMP Alliance students have increased exhibited exponential growth in enrollment in STEM programs, STEM graduation rates and entrance into the STEM workforce.

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