Board 103: Work in Progress: NSF S-STEM Program: Recruitment, Engagement, and Retention: Energizing and Supporting Students with Diverse Backgrounds in Mechanical Engineering

Jamie R. Gurganus, University of Maryland, Baltimore County

Jamie Gurganus works in the Mechanical Engineering Department at UMBC, focusing in the field of Engineering Education. She serves as the Associate Director of Engineering Education Initiatives for the College of Engineering and IT at UMBC and recently as Co-Director of Advancing Engineering Education Excellence (AEEE). Her research is focused on solving problems relating to educating engineers, teachers, and the community. She seeks to identify best practices and develop assessments methods that assist teachers with student engagement, helping them to be successful throughout the STEM pipeline. A few of these key areas include enhancing student's spatial abilities (k-12 and higher education), integrating service learning into the classroom, implementing new instructional methodologies, and design optimization using additive manufacturing.

Dr. Liang Zhu, University of Maryland, Baltimore County

Liang Zhu received her B.S. in Engineering Thermophysics from the University of Science and Technology of China, Hefei, Anhui, China, in 1988, and Ph.D. in Engineering from the City University of New York, New York, USA, in 1995. Currently, she is a Professor of Mechanical Engineering at the University of Maryland Baltimore County (UMBC). Her research fields include using nanotechnology to improve treatment outcomes of patients. She is also interested in Engineering Education research, and currently she serves as the Director of Mechanical Engineering S-STEM Scholarship Program at UMBC.

Dr. Charles D. Eggleton, University of Maryland, Baltimore County
Shuyan Sun

NSF S-STEM Program: Recruitment, Engagement, and Retention: Energizing and Supporting Students with Diverse Backgrounds in Mechanical Engineering (Work-in-Progress)

Abstract

Recognizing current and future needs for a diverse skilled workforce in mechanical engineering and the rising cost of higher education that acts as a barrier for many talented students with interests in engineering, the NSF funded S-STEM project at a state university focuses resources and research on financial support coupled with curricular and co-curricular activities designed to facilitate student degree attainment, career development, and employability in STEM-related jobs. This program has provided enhanced educational opportunities to more than 90 economically disadvantaged and academically talented undergraduate students in the Mechanical Engineering Department in the past eight years. It is expected that approximately 45 academically talented and financially needy students, including students transferring from community colleges to four-year engineering programs will receive scholarship support in the next 5 years, with an average amount of $6,000 per year for up to four years to earn degrees in mechanical engineering at the University of Maryland Baltimore County (UMBC).

Through scholarships and supplemental support services, this program promotes full-time enrollment and will elevate the scholastic achievement of the S-STEM scholars, with a special emphasis on females and/or underrepresented minorities. It will provide a holistic and novel educational experience combining science, engineering, technology and medicine to improve student retention and future career prospects. The project builds on an established partnership between the state university and community colleges to improve and investigate the transfer experience of community college students to four-year programs, student retention at the university, and job placement and pathways to graduate school and employment. A mixed methods quantitative and qualitative research approach will examine the implementation and outcomes of proactive recruitment; selected high impact practices, such as orientation, one-to-one faculty mentoring, peer mentoring, and community building; participation by students in research-focused activities, such as research seminars and undergraduate experiences; and participation by students in career and professional development activities.

In this paper, preliminary data will be presented discussing the attitudes and perceptions of the s-stem scholars and comparing students in scholarly programs and non-programmed situations.

This research was supported by an NSF S-STEM grant (DUE-1742170).

Introduction

To meet the need for a highly trained workforce that satisfies current and future technological needs of society [1], an S-STEM scholars' program, sponsored by National Science Foundation (NSF), was proposed and created for mechanical engineering students at the University of Maryland Baltimore County (UMBC). The specific goal of the proposed Mechanical Engineering (ME) S-STEM program is to provide enhanced educational opportunities to 20 economically disadvantaged and academically talented students annually, with emphasis on underrepresented minorities and females. The selected students receive scholarships and supplemental support services to facilitate their full-time enrollment to improve scholastic achievement. Building on lessons learned from a previous ME S-STEM Program at UMBC, the current program, launched in Fall 2018, leverages existing resources and developed new activities. The aim is to provide the scholars a holistic and novel educational experience that combines science, engineering technologies, and biomedicine to improve student retention and future career prospects. It is expected that the effective practices identified by the program will be disseminated to other engineering programs at the university.

This five-year project aims to achieve the following specific objectives:

1. Implement proactive recruitment approaches and enhance cooperative relationships between the university and local community colleges, increasing the number of transfer students in ME program. Pre-transfer recruitment efforts will be carried out to help students understand the abundant educational opportunities at the university and improve the transfer rate.

2. Retain and graduate an increased number of students in Mechanical Engineering with special emphasis on underrepresented minorities and women, by providing scholarships, academic intervention, proactive faculty mentoring, and an institutional support infrastructure designed to increase retention of the participants and their success.

3. Incorporate research experiences into the education curriculum through research seminars and access to research laboratories in bioengineering as a vehicle to facilitate the participants' retention, to supplement their skill base, and to provide successful paths for graduate study.

4. Provide students with academic and professional development opportunities through internship opportunities and workshops that identify potential industrial and government job placements. The scholarships are awarded to 20 students annually.

This paper will discuss preliminary findings from a pre-survey that was conducted at the beginning of the fall 2018 semester. Current assessment includes the following:

1. Current perceptions and attitudes of research and engineering between gender, transfer students and race/ethnicity specifically to both mechanical and S-STEM population.
2. Assessment of S-STEM scholars compared to students who are non-affiliated to a scholar program.

Background of the program

UMBC mechanical engineering department received NSF S-STEM grants in 2010 and 2014, focusing on recruitment, retention, graduation and post-graduation for mechanical engineering students with specific emphasis on underrepresented groups. Additionally, relationships with 14 local community colleges were established to serve the transfer student population. At this time, the S-STEM program has served 84 low-income, academically talented students.

Support services for the S-STEM students include faculty mentoring, peer support, summer orientation, access to tutoring, and help with identifying careers and research immersions. The project also fostered a formal consortium relationship between the university and local community colleges, providing a doorway for easy transfer of community college students to the university 4-year programs.

Previous impacts of the program showed an increased number of students with diverse backgrounds to include including 20% African Americans, 15% Hispanics, and 27% women [2][3]. The connection with local community colleges and proactive recruitment strategy were particularly strong components of the program. Overall, 39% of the scholars were transfers from 2-year local community colleges [4]. Results also indicate that faculty mentoring, monetary support, and an integration of research into education played strong roles in student retention and post-graduation placement. The overall retention rate in 2017 was 88%. Through March 2017, 49 scholars (58%) completed the BS degree in ME with an average GPA at graduation of 3.53/4.0, 27% of them are pursuing graduate degrees in a STEM major, 67% of them are now working in a STEM industry.

The program was built from both best practices in research and lessons learned from previous years from the grant [2][3]. Specifically, a S-STEM scholar will be connected to faculty mentor, receive monetary support, and provided with placement and understanding of internships and research experiences. Involving research experiences in our interdisciplinary bioengineering research labs has helped attract more female and minority students to mechanical engineering and expanded their skill base [5]-[9]. Another successful component of the program identified by the scholars were the research seminar series.

Improvements to the program

Assessing previous populations of S-STEM Scholars concluded a need for additional improvements to the program. Students stated that they preferred more invited speakers who graduated from the university (alumni). Students also wanted to have speakers from industry and government agencies, giving them a greater understanding of potential careers and enable them to identify potential contacts. In this new academic year and cohort, speakers will include the above request (industry and university alumni). Furthermore, additional research related activities will be added to support our scholars' pursuit of graduate degrees. These activities will include meetings with faculty early in their academic careers, visiting research labs, featuring scholars' research on our website, and organizing workshops for mechanical engineering graduate school application process.

Research methodology

In Fall 2018, a pre-survey consisting of 19 questions and was administered to both S-STEM scholar and non-affiliated S-STEM mechanical engineering students. Using a 6-item Likert survey, students were asked to assed their perceptions and attitudes regarding each of the constructs. At the end of the Spring 2019 semester, a post-survey will be administered to the population for comparison.

Survey Instrument

In partnership with the psychology department, a survey was developed containing measurable items regarding their attitudes, perspectives, science/engineering identity, and research self-efficacy. Below are the measurable constructs and their items showing reliability.

1. Research Self- Efficacy: Measured by six items from the Scientific Self-Efficacy Scale [10] that assesses students' ability to function as a scientist. Sample items include "use technical science skills", "generate a research question", and "use scientific literature and/or reports to guide research and develop theories." High reliability was reported in previous studies [10][11].
2. Science/Engineering Identity: Scientific identity will be measured by five items from the Scientific Identity Scale [10] that ask students to assess how much being a scientist/engineer is viewed as part of how they identify themselves. Sample items include "have a strong sense of belonging to the community of scientists", "feel like I belong in the field of science", and "have come to think of myself as a scientist." High reliability was reported in previous studies [10][11].
3. Expectations and Goals: These items were developed by the research team, aimed at the student's confidence in achieving their goals in academia and research.
4. Academic Integration: Measured by six items from the *Your First College Year survey* conducted by the Higher Education Research Institute at UCLA. Sample items include "seek feedback on academic work" and "explore topics". Reliability was .76 for academic integration [12].
5. Sense of Belonging to the Program: The 3 items in this construct was adapted from the Sense of Community Index [13], which was developed based on McMillan and Chavis's (1986) theory of psychological sense of belonging. Sample items include "I can trust people in the program" and "I expect to be a part of the program for a long time." Reliability of this measure was high [13].
6. Sense of Belonging to the Campus: Measured by five items [14], including "I feel comfortable on campus" and "My college is supportive of me." Reliability was .90 in Johnson (2012).

Table 1 further expands each of the constructs and their measurable items. Additionally, the reliability of each construct is reported.

Table 1: Survey Items and Internal Consistency

Research Self- Efficacy[2] (α = .929) 9 items
Use technical science skills (use of tools, instruments, and/or techniques)
Generate a research question to answer
Formulate a hypothesis about a research question
Determine which data/observations to collect
Design a strategy to collect data for a study
Record data that is collected during an experiment
Analyze data collected during an experiment
Create explanations for the results of the study
User scientific literature and/or reports to guide research
Science Identity (α = .88)[3] 5 items
I have a strong sense of belonging to the community of engineering
I derive great personal satisfaction from working on a team that is doing important research
I have come to think of myself as an 'engineer'
I feel like I belong in the field of engineering
The daily work of an engineer is appealing to me
Expectations and Goals(α = .69)[3] 4 items
I am confident that I will achieve my career goals.
I am excited about the idea of scientific research.
I am confident that I will achieve my academic goals.
I expect to feel comfortable going to ME faculty and staff if I have a problem.
Academic Integration (α = .82)[1] 5 items
Understand what your professors expect of you academically
Develop effective study skills
Adjust to the academic demands of college
Manage your time effectively
Develop close friendships with other students.
Sense of Belonging to the program (α = .86)[3] 3 items
I feel a sense of belonging with STEM-oriented program, organization or community at the university (e.g. ASME, SWE, NSBE, etc.).
I feel a sense of belonging to a STEM major at the University
I feel a sense of belonging to a STEM department at the University
Sense of Belonging to the campus (α = .877)[3] 5 items
I feel a sense of belonging to the university
I feel that I am a member of the campus community.
I feel comfortable on campus.

I would choose this university over again.
This University is supportive of me.

1 Four-item scale: 0-25=Very Easy, 25-50=Somewhat Easy, 50-75=Somewhat Difficult, 75 100=Very Difficult
2 Five-point scale: 0-20=Not at all confident, 20-40=Somewhat Confident, 40-60=Moderately Confident 60-80=Very Confident, 80-100=Absolutely Confident
3 Five-point scale: 0-20= Strongly Disagree, 20-40=Disagree, 40-60=Neither agree or Disagree 60-80=Agree, 80-100= Strongly Agree

The data collected in this study was numerically coded; computer tabulated and analyzed using the Statistical Package for the Social Sciences (SPSS). Procedures used for the analyses of data included frequency counts, calculations of means and standard deviations, t-test for significance, Shapiro-Wilk test of normality, reliability coefficients (Cronbach's alpha), and One-way Analysis of Variance (ANOVA).

Data and Results

Demographics of the Participants

Dissemination of the survey include S-STEM scholars and non-scholars in several mechanical engineering classes. A total of 60 validated pre-surveys were completed and assessed. Below, in Table 2, shows the demographics of the population of participants in the survey.

Table 2: Demographics of Survey Participates

Demographic		Total N=60	Transfer Students	S-STEM Scholar
Gender	Male	65% (39)	22% (13)	22% (13)
	Female	35% (21)	15% (9)	18% (11)
Race/Ethnicity	Hispanic or Latina	16.7% (10)	3% (2)	8% (5)
	Asian	13.3% (8)	5% (3)	3%(2)
	Black/African American	20% (12)	5% (3)	5% (3)
	White	55% (33)	22% (13)	25% (15)
	Other	11.7% (7)	3% (2)	5%(3)
Total	N	60	22	24

Students who reported American Indian or Alaska Native, Native Hawaiian, or other Pacific Islander were excluded from the analysis due to small or no population sizes.

Out of the 60 participants, 24 current S-STEM scholars reported. Below are the demographics from this group (Table 3).

Table 3: S-Stem participant Demographics

N=24		Percent
Gender	Male	54%
	Female	46%
Transfer Student		54%
Race/Ethnicity	Hispanic or Latina	21%
	Asian	13%
	Black or African American	13%
	White	63%
	Other	13%
First Generation		42%

Table 4 shows the class standing, freshman to senior, of the participants in the analysis.

Table 4: Class standing

Class	Frequency	Percent
Freshman	4	7%
Sophomore	10	17%
Junior	17	28%
Senior	29	48%
Total	60	100%

Gender comparison

In Table 5 below reports the means and p-values of the assessed items as it relates to men and women participants.

Table 5: Gender Assessment

N=60	Your gender:		P-Value
	Male	Female	
Research Self-Efficacy	71.05	57.14	.000*
Science/Engineering Identity	88.21	78.48	.002*
Expectation Goals	85.51	79.05	.050*
Academic Integration	57.57	50.75	.101
Sense of Belonging to the program	79.32	76.83	.54
Sense of Belonging to the Campus	80.95	82.67	.639

**statistical significance at p=.05 level*

A one-way anova analysis revealed a significant difference between men and women's research self-efficacy, $F(1,58)=18.95$, $p<.0005$ and engineering identity $F(1,58)=10.62$, $p<.005$. Male engineering students currently feel very confident in their abilities (M=71.05) to conduct and carry out research whereas the women feel only moderately confident (M=57.14). Additionally, the male participants were significantly (absolutely) confident in their engineering identity (M=88.21) verses their female colleagues who were very confident (M=78.48).

Further results also showed a notable difference in the expectation and goals between the genders $F(1,58)=4.0$, $p=.05$. The male population strongly agreed (M=85.5) in their abilities to succeed in their career and research goals whereas the female population moderately agreed (M=79.0)

Table 6 reflects the mean analysis of gender comparison of S-STEM scholars.

Table 6: S-STEM Gender Comparisons

N=24	Male	Female	P-value
Research Self-Efficacy	69.74	61.41	.127
Science Identity	91.08	84.36	.085
Expectation Goals	88.08	85.45	.504
Academic Integrity	58.46	43.00	.036*
Sense of Belonging Program	87.69	85.45	.036*
Sense of Belonging Campus	85.85	89.09	.634

**statistical significance at p=.05 level*

A significant difference was shown in the academic integrity $F(1,22)= 5$, $p<.05$ and sense of belonging to the program $F(1,22)=5$, $p<.05$. Males in the S-STEM program have a higher sense of belonging to the program over the females. Additionally, females found it to be easier to integrate academically over their male counterparts.

Transfer student comparison

One of the bigger goals of the program is recruiting and retaining transfer students into a four-year mechanical engineering program. Table 7 shows the premilitary results from the study of transfer students compared to native university students for the entire population.

Table 7: Transfer Students vs. Non-transfer

	Transfer (n=22)	Native (n=38)	P-Value
Research Self-efficacy	66.67	65.91	0.835
Science Identity	84.73	84.84	0.972
Expectation Goals	84.09	82.76	0.689
Academic Integration	51.75	57.03	0.207
Sense of Belonging: Program	81.21	76.84	0.276
Sense of belonging: Campus	81.82	81.41	0.909

**statistical significance at p=.05 level*

Assessing the transfer participants as compared to the native population reveals no significant difference. However, several constructs display notable means including academic integration (M=51.75, M= 57.03) and research self-efficacy (M=66.75, M=65.51)) in the transfer and native student population, respectively. Both groups of students feel that integration into college academically is somewhat difficult. Additionally, both populations feel very confident in their ability to succeed in research.

Table 8 reflects the results of S-STEM transfer students compared to native S-STEM scholars.

Table 8: S-STEM Transfer vs. Native

	Transfer	Native	P-Value
Research Self-Efficacy	63.08	69.29	0.260
Science identity	86.77	89.45	0.503
Expectation Goals	86.15	87.73	0.689
Academic Integration	47.92	55.91	0.295
Sense of Belonging: Program	87.69	85.45	0.295
Sense of Belonging: Campus	88.92	85.45	0.634

**statistical significance at p=.05 level*

As seen with the general population, S-STEM transfer students vs. Native S-STEM scholars show no significant difference. However, examining the mean values, transfer S-STEM scholars found it to be somewhat easier to academically integrate into the program over their native colleagues.

S-STEM Scholars compared to Non-Scholars

The S-STEM population was assessed in their perceptions and attitudes and compared to non-scholars. Non-scholars were identified as students who were not associated with any other programs on campus. Table 9 reflects the results from the analysis.

Table 9: S-STEM scholars & Non-Scholar

	S-STEM	Non-scholar	p-value
Research Self-Efficacy	65.93	68.02	0.573
Science identity	88.00	81.91	0.072
Expectation Goals	86.88	80.43	0.076
Academic Integration	51.74	55.68	0.414
Sense of Belonging: Program	86.67	71.30	0.000*
Sense of Belonging: Campus	87.33	76.91	0.004*

**statistical significance at p=.05 level*

Preliminary results revealed a statistical significant difference in both a sense of belonging to the program $F(1,46)=16.81$, $p<.0005$ and campus $F(1,45) = 9.34$, $p<.004$. S-STEM scholars strongly agree that they feel a sense of belonging to both the program (M= 86.67, M=71.30) and campus (M=87.33, M=76.91) whereas non-scholars only moderately agree feeling inclusiveness to the campus.

Race/Ethnicity

Preliminary results of Race and Ethnic population is shown in Table 10.

Table 10: Race & Ethnicity Preliminary Results

	Asian	Black or African American	White	Hispanic or Latina
Research Self-Efficacy	64.72	62.59	68.42	70.22
Science/Engineering Identity	85.00	85.00	84.73	84.80
Expectations and Goals	83.13	84.58	83.03	85.00
Academic Integration	53.13	58.64	55.65	61.50
Sense of Belonging in Program	80.83	80.00	77.98	77.33
Sense of Belong to Campus	84.50	84.33	80.63	82.40

**statistical significance at p=.05 level*

Results from comparing the means, revealed no significant difference among the groups. However, notable themes among the groups showed academic integration was somewhat difficult (M=53.13- 61.5). Although not '*absolutely confident*,' most of the groups felt moderately to very confident in their research self-efficacy.

Table 11: S-STEM Race & Ethnicity Preliminary Results

	Asian	Black or African American	White	Hispanic or Latina
Research Self-Efficacy	71.11	56.30*	69.78	74.67
Science/Engineering Identity	86.67	80.00	90.93	89.60
Expectations and Goals	93.33	80.00*	89.00	85.00
Academic Integration	38.33	51.67	54.29	68.00
Sense of Belonging in Program	88.89	80.00*	90.67	84.00
Sense of Belong to Campus	90.67	81.33	89.33	86.40

**statistical significance at p=.05 level*

S-STEM population race and ethnicity (Table 11) reveals significant difference among the groups in research self-efficacy $F(3, 24)=2.9$, $p<.05$, expectations and goals $F(3,24) = 3.2$, $p<.05$, and sense of belonging to the program $F(3, 23)=4.3$, $p<.05$. Groups identified in the African American/Black population showed less confidence in their ability to perform in research. Additionally, they moderately agreed they had confidence in achieving their goals over the other groups which strongly agreed. Finally, this same group had the least sense of belonging to the program over the other racial and ethnic groups.

Conclusion and Future work

Initial assessment of the S-STEM ME program at UMBC, although preliminary, revealed impactful results. S-STEM students feel a stronger sense of community on the campus over the non-scholar affiliated colleagues. Additionally, they have strong sense of being able to integrate academically easier. Gender comparisons reveled that women in the S-STEM perceive to have an easier time integrating academically as well as transfer students in the program.

Future work will include post-analysis of the current S-STEM population compared to the non-S-STEM students. Moreover, students in S-STEM post analysis will be compared to the pre-assessment data.

This research was supported by an NSF S-STEM grant (DUE-1742170).

References:

1. US Department of Education. *Strengthening education: meeting the challenge of a changing World*, 2006, http://www.ed.gov/about/inits/ed/competitiveness/strengthening/strengthening.pdf
2. Dowell, K.. *Evaluation of the University Mechanical Engineering S-STEM Program: Final Report*, 2014.
3. Dowell, K.. *Evaluation of the UNIVERSITY Mechanical Engineering S-STEM Program: Year 2 Report*, 2016.
4. Zhu, L., Arola, D., Spence, A., Romero-Talamas, C., and Eggleton, C.. *Recruiting and supporting transfer students to mechanical engineering program at UNIVERSITY.* Summer Biomechanics, Bioengineering, & Biotransport Conference, National Harbor, MD, 2016. Paper number SB3C-2016-23.
5. Zappe, S.. *Describing mechanical engineering: devising a strategy for recruiting underrepresented students*, A report from ASME International Engineering Education Conference, http://files.asme.org/asmeorg/Education/College/Faculty/18355.pdf.
6. Zhu, L., Arola, D., Eggleton, C., and Spence, A.. *Education activities of bioengineering for undergraduate students at UNIVERSITY*, #SBC2011-53149, June 2011, Famington, PA.
7. Hensel, N.H. and Cejda, B.D.. *Tapping the potential of all: undergraduate research at community colleges*. Council on Undergraduate Research. Washington, D.C., 2014.
8. Lopatto, D.. *Undergraduate research experiences support science career decisions and active learning*. CBE - Life Sciences Education Vol. 6, No. 4, pp. 297-306, 2007.
9. Lopatto, D.. *Undergraduate research as a high-impact student experience*. Peer Review, 12(2), 2010.
10. Chemers, M. M., Syed, M., Goza, B. K., Zurbriggen, E. L., Bearman, S., Crosby, F. J., Morgan, E. M.(2010). The role of self-efficacy and identity in mediating the effects of science support programs(Technical Report No. 5). Santa Cruz: University of California.
11. Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. (2011). Toward a model of social influence that explains minority student integration into the scientific community. Journal of Educational Psychology, 103(1), 206.
12. Sharkness, J., & DeAngelo, L. (2011). Measuring student involvement: A comparison of classical test theory and item response theory in the construction of scales from student surveys. Research in Higher Education, 52(5), 480-507.
13. Chavis, D.M., Lee, K.S., & Acosta J.D. (2008). The Sense of Community (SCI) Revised: The reliability and validity of the SCI-2. Paper presented at the 2nd International Community Psychology Conference, Lisboa, Portugal.
14. Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. *Journal of College Student Development*, *53*(2), 336-346.
15. Martin, S., Marshal, A., and Zhu, L.. *S-STEM programs for engineering and computing transfer students*. 22nd National Conference on Students in Transition, Baltimore, October 2015.
16. University of Maryland Baltimore County. *Student data*, All student data were compiled by Office of Institutional Research at UNIVERSITY, 2017.