Board 389: Student Success in Engineering Through Customized Support and Internal and External Partnerships

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STEM Scholars Program: Student Success in Engineering Through Customized Support and Internal and External Partnerships

> Although a sense of belonging can mirror students' prior experiences, it is most directly shaped by the broader campus climate and their daily interactions with other students, faculty, staff, and administrators on campus -- and the messages those interactions convey. Students who perceive themselves as belonging are more likely to persist because it leads not only to enhanced motivation but also a willingness to become involved with others in ways that further promote persistence.
>
> (Tinto, 2016)

Introduction

The purpose of this qualitative study is to report on the structure and impact of a single institution Track 2 NSF S-STEM (Scholarships in Science, Technology, Engineering, Mathematics) project titled "Increasing Retention and Success of Students from Low-Income Backgrounds in Civil Engineering." Over the past three years, our *Mizzou Engineering STEM Scholars Program* at the University of Missouri-Columbia has provided two-year scholarships to a total of 32 freshmen and sophomores from low-income backgrounds. Each year, our program supports a cohort of 8 to 13 students. In addition to the financial support during the freshmen and sophomore years, Scholars receive customized academic mentoring to succeed in 8 courses considered "gateway" to engineering (Gateway 8 - math, basic sciences, and introductory engineering classes). During the junior and senior years, we prepare the Scholars for workforce training as well as research/graduate studies with support from our industry partners and research faculty members, respectively. All through the four years of the Scholars program, we have endeavored to create an environment that fosters a sense of belonging to a community that encourages academic persistence, high levels of engineering self-efficacy, and high achievement. These efforts also include a monthly one-on-one progress check-ups with the project's principal investigator, regular surveys to evaluate the program and for knowledge generation (NSF, 2010) and dissemination, and participation in team-building events that involved community service projects, field trips, cohort meetings, and social events. The STEM Scholars Program with an original focus on civil engineering had become very popular, and as a result of applicant demand, has now been expanded to include applicants from all other undergraduate engineering programs.

Background Literature

Completing a four-year degree in STEM fields is not an easy task, and the task is significantly more difficult for students graduating from high schools with high percentages of low-income students. To get a sense of the difficulties students from low-income schools must face, consider the statistics that were reported in the tenth annual High School Benchmark Report (NSCRC, 2022), a report that includes over one million high school graduates per year from public and private high schools. Sixty-five percent of students from higher-income high schools immediately enroll in college after high school graduation, but only 49% of students from low-income high schools do so. Once in college, 86% of students from higher-income high schools persist in college for at least two years in contrast to 76% of students from low-income high

schools. For students who graduated from high school in 2015, 52% of students from higher-income high schools completed a college degree within six years of graduation as compared to 30% of students from low-income high schools. More germane to the present study, 18% of students from higher-income high schools completed STEM degrees within six years of high school graduation compared to 9% of students from low-income high schools. Moreover, of the students who completed STEM degrees, 19% of the students from higher-income high schools completed a degree in engineering compared to 13% of the students from low-income high schools.

These statistics lay bare major imbalances that exist between higher- and lower-income students. However, we must go beyond these numbers to identify the persistent problems that students from lower-income environments must confront to be successful at the same rates as students from higher-income environments. Certainly, the high costs of post-secondary education discourage or prevent many low-income students from enrolling in college immediately after high school. Scholarships can be a tremendous help in this regard, but even with scholarships, many low-income students are averse to entering college, and once they do enter do not persist beyond two years and many more do not persist to completion. A major cause for the lack of persistence for low-income students has been attributed to their feelings of alienation or isolation within the college experience (AAAS, 2021). Low-income students are often high achievers in high school, and yet when they enter college, they may suffer from anxiety stemming from their beliefs that their academic performance is perceived by others as inferior and that they will one day be exposed as impostors or frauds not on an academic par with their peers (Sakulku & Alexander, 2011). Negative self-perceptions act as a confirmation bias that feeds into their negative stereotypes (Seymour & Hunter, 2019). Their negative thinking can be manifested as "I am not as smart as my peers and therefore I could never succeed in an engineering program." These stereotype threats are associated with lower self-efficacy and a lack of belonging to the academic community (Stephens et al, 2012; Strayhorn, 2018; Totonchi et al., 2021).

"STEM students' sense of belonging can serve as a leading indicator of academic performance and persistence" (AAAS, 2023, p. 3). Because belonging has such a strong link to academic success, particularly for low-income students, many STEM programs have begun to actively monitor and take action to ameliorate the negative consequences stemming from a lack of belonging. The American Association for the Advancement of Science (AAAS, 2023) recently reported that out of 105 STEM programs surveyed, 60% had implemented strategies to improve students' sense of belonging. Although it is likely the case that not all students experience a sense of belonging in the same ways, there is an existential quality to belonging that is shared by most individuals. That existential quality entails a feeling of becoming a part of something greater than the self, such as a relationship with another, a kinship with peers, or a membership in a group (Hacker, 1994). To identify with a group of individuals who share common beliefs, goals, or values can dispel feelings of isolation and instill a sense of belonging.

Several strategies have been developed over recent years that have been shown to increase the sense of belonging in low-income STEM students and have been associated with increases in academic persistence and consequently academic performance (AAAS, 2023). Two of the most frequently used strategies involve faculty mentoring and academic advising. In addition, cohort-based STEM programs have proven to create environments that are conducive to student success.

STEM Scholars' Program Features

Our STEM Scholars program, custom-designed for the successful implementation of the NSF-funded S-STEM project, includes a multi-pronged approach to improve retention and student success (Fig. 1). The focus during the Scholar's freshmen and sophomore years is on building a strong foundation in the Gateway 8 (G8) courses. These eight courses in math, basic sciences, and introductory engineering (Table 1) are often the primary reason for attrition from engineering programs and pose significant hurdles to students from low-income backgrounds. Emphasis during the Scholar's junior and senior years is on personal/professional development, preparation for graduate studies, and workforce training.

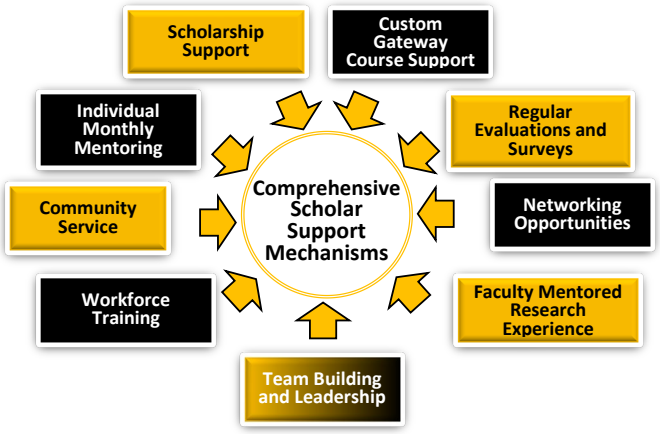

Fig. 1: Comprehensive Scholar support mechanisms for improved retention and student success.

Table 1: The Gateway 8 – Course Sequence, Numbers and Titles

Year	Semester	Courses Details
Freshman	**1st**	Math 1500[1] – Analytic Geometry and Calculus I
		Chem 1320[2] – College Chemistry 1
	2nd	Math 1700[1] – Calculus II
		Phys 1750[2] – University Physics I
Sophomore	**1st**	Engr 1200[3] – Statics and Elem. Strength of Materials
		Cv Eng 3010[4] – Decision Methods for CE Design
		Cv Eng 3200[2] – Fund. of Environmental Engineering
	2nd	Engr 2200[3] – Intermediate Strength of Materials

1. Calculus, 2. Basic Science, 3. Engineering Analysis, and 4. Writing Intensive

The comprehensive Scholar support mechanisms include:

1. Financial support via STEM Scholarships during freshman and sophomore years.
2. Monthly one-on-one progress check-up meetings with the Principal Investigator (PI), in addition to continuous early alert using a learning management system platform.
3. Customized academic support in eight Gateway (G8, Table 1) courses (math, basic sciences, and introductory engineering courses).

4. STEM Cohort networking with regular cohort meetings, community-engagement service projects, field trips, and professional/personal development seminars to improve "Scholars' Sense of Belonging."
5. Team-building events involving all STEM Scholars, internal and external partners, and the core STEM Team, including the annual Meet and Greet event every Fall with the entry of a new cohort, and the annual banquet to recognize Scholar accomplishments in late Spring.
6. Workforce development with external partners for internship/coop opportunities and with department faculty for hands-on graduate research training in funded research projects (training for graduate studies).
7. Regular internal and external program evaluation surveys and focus group meetings of Scholars for knowledge generation and finetuning program support features.
8. Monitoring of Grade Point Averages each semester and follow up with students whose grades may be slipping below program expectations.

Additionally, the STEM Project Leaders also currently participate in an NSF-STEM Hub (Research on Organizational Partnerships in Education and STEM (ROPES) Hub coordinated by the Virginia Tech, Blacksburg, VA) to learn from and contribute to the knowledge base of how inter- and intra-institutional partnerships can enhance the support provided to engineering students from low-income backgrounds.

Financial Support and Good Standing

Scholars were selected for the program based on their financial need and academic record. They were supported with scholarships of $8,500 during their freshmen year and $9,000 during their sophomore year, paid in two equal installments each semester of the academic year. Renewal of STEM Scholarships required Scholars to be in good standing. Requirements for good standing included maintaining a 3.0 GPA, participating in one-on-one meetings with the PI, participating in all the mandated evaluations and surveys, and in a majority of STEM meetings and service projects. The scholarship, a financial incentive, allows Scholars to focus on their coursework during a time when they are to complete important foundational math, basic sciences, and introductory engineering courses (G8) and not get distracted with part-time employment to support their education. Restricting NSF support for the first two years also allows us to award STEM scholarships to twice as many applicants. During their junior and senior years, Scholars are networked with our industry partners so that they can receive internship support (workforce training) and support from faculty for undergraduate research experience (training to encourage exploring graduate study opportunities). These training opportunities allow Scholars to partly defray education costs. Scholars, at this stage in their education, typically also receive scholarships from other sources to offset the loss of NSF STEM Scholarship during their junior and senior years.

Monthly One-on-One Progress Check-in

The project PI meets monthly with each Scholar in an "one-on-one" format to discuss their academic and professional progress during their entire undergraduate program. These monthly meetings are preceded by the Scholars completing a pre-meeting Qualtrics survey identifying issues that they want discussed at the one-on-one meeting. The STEM Team and the PI have

ongoing access to the Scholars' academic performance including performance in the current semester's coursework. The system allows the project team and advisers to share messages with instructors and students to provide timely academic and counselling support needed. Kudos option, which are course-based indicators that instructors can send to students to encourage positive performance in class, is also available as one of the tools in our retention strategy.

"Early alert" flags using a feature embedded within the *Canvas* learning management system, used for all coursework, allows timely follow-up. This platform also allows the team of advisors and instructors to monitor Scholar academic progress and for scheduling meetings with the Scholars. The monthly one-on-one meetings have improved Scholar "accountability" while also providing the Scholars with a sense of "caring oversight."

Customized Tutorial Support

Based on discussions at the one-on-one meetings, Scholars are recommended customized tutorial support available at the College of Engineering and the Campus Learning Center for all math, basic sciences, and introductory engineering classes. Depending upon the need, peer mentoring and other resources are also made available to the Scholars. Scholars have made steady progress towards completing their G8 courses in a timely manner as well as progress expected towards completing all the degree requirements in 4 years.

Professional and Personal Growth Activities

The project team holds multiple events each year to foster networking and building a community of STEM Scholars with the primary goals of enhancing "the sense of belonging" and "increasing the awareness of the community around us" (Fig. 2). These activities include professional development seminars, field trips, networking and leadership opportunities, and personal growth opportunities through community service projects. The Meet and Greet welcome every fall, and the Scholar Recognition Banquet each spring, allows all the Scholars to network with the core STEM team and our internal and external partners in an informal setting.

In addition to academics, Scholars are encouraged to take up leadership positions in student organizations (American Society of Civil Engineers (ASCE), Engineering Student Council (ESC) and National Society of Black Engineers (NSBE)) and participate in student teams (Concrete Canoe, Steel Bridge, Robotics, etc.). We have had a field trip to the Coreslab precasting yard and plan for more field trips this year. Scholars have also attended several seminars organized within the College of Engineering and a mentoring session with some of our External Partners under the auspices of the Civil Engineering Association of Distinguished Alumni (CEADA).

Workforce and Research Training

It is encouraging to report that all of the Scholars from Cohort 1 (Fall 2021 entry) have completed their G8 coursework and have undertaken internships/research assignments as a part of their workforce/graduate training components of the STEM Scholars Program effective Summer 2023. They have worked with our external partners, other industry partners, and faculty

for this training and look forward to continuing such training during Summer 2024. Some Scholars from Cohort 2 (Fall 2022) have participated in internships and as undergraduate research assistants in faculty-led research projects ahead of schedule, even as they are nearing completion of G8 coursework. It is heartening to note that we have been successful in accomplishing one of the project goals, which is retention of Scholars supported on NSF STEM Scholarships in STEM fields.

Fig. 2: STEM Scholars Program -Professional networking and personal growth activities during 2023. (a) 2023 STEM Scholar Recognition Banquet for Cohorts 1 and 2 – April 2023, (b) 2023 Meet and Greet welcoming ceremony for Cohort 3 – August 2023, (c) Scholars volunteering at the Food Bank Pantry – March 2023, (d) Packing individual food packets from bulk food donations at the Food Bank – October 2023, and (e) Painting ceilings at a new Habitat for Humanity subdivision home – November 2023.

Evaluations and Surveys

As an ongoing component of generating knowledge to share with NSF and other STEM programs nationwide, as well as to enhance our own internal Scholar support mechanisms, we have been conducting regular evaluations and surveys of our Scholars as well as University of Missouri and External Partners. We monitored students' progress across their two-year scholarships individually and longitudinally with regular evaluations. Our multi-pronged evaluation strategy consisted of multiple administrations of the Sense of Community-2 survey and an Engineering Self-Efficacy survey (Table 2). Each was administered at the beginning and end of the two years and again at a point mid-way through. The Sense of Community-2 (Chavis, Lee, & Acosta, 2008) measures a student's feelings of belonging to a community and

commitment to one another, and feelings that each member's needs will be met by the community.

Table 2: Typical Data Collection Schedule for a STEM Scholar Cohort

Data	Year 1		Year 2	
	Fall	**Spring**	**Fall**	**Spring**
Quantitative	SOC[1] (Early) SEES[2] (Early) GPA[3] (End)	SOC[1] (Late) SEES[2] (Early) GPA[3] (End) SM[4] (End)	GPA[3] (End)	SOC[1] (Late) SEES[2] (Early) GPA[3] (End) SM[4] (End)
Qualitative	Monthly Mtgs	Monthly Mtgs Focus Groups PS[5]	Monthly Mtgs	Monthly Mtgs Focus Groups PS[5]

[1] Sense of Community, [2] Self-Efficacy of Engineering Students, [3] Grade Point Average (Overall and Gateway 8), [4] Success Measures (Various), [5] Program Satisfaction

The Engineering Self-Efficacy survey (Frantz, Siller & Demiranda, 2011) measures students' judgments concerning their academic performance in engineering courses and an engineering program, their expectations about an engineering career, and their persistence in pursuing an engineering education. In addition, at the end of each academic year, students participated in a focus group to discuss their personal experiences in the program and offer suggestions for change. Grade point averages from each semester were recorded and correlated with self-efficacy measures.

As we continue to aggregate SOC and SEES data from our three cohorts over the evaluation periods outlined in Table 2, and correlating them to Scholar performance, some overall trends of successes are already apparent in the academic performance of our Scholars, progress towards degree, and retention to-date as presented in Table 3. Cohorts C1 admitted in Fall 2021, C2 in Fall 2022, and C3 in Fall 2023, have completed 5 semesters, 3 semesters and 1 semester to date, respectively. The average progress towards degree completion was computed based on actual credit hours completed as a percentage of the credit hours expected at that particular Scholar stage (semesters completed) for a timely 4-year degree completion.

Table 3: Outcomes of the STEM Scholars Program with respect to Scholars' academic performance, progress towards degree, and retention in STEM

Cohort	**Original Size**	**Graduated**	**Transferred to other STEM programs**	**Continuing in the program**	**Continuing Scholars**			**Retention in STEM**
					Semesters completed	**Average cumulative GPA**	**Average progress towards degree[+]**	
C1	8	1*	1	6	5	3.418	94%	100%
C2	12	0	1	10	3	3.263	91%	92%
C3	13	0	0	13	1	3.517	100%	100%

***** Only Masters Scholar in the program graduated after 4 semesters.

+ Progress expressed as % of credits completed towards a degree in 4-years, at comparable stages.

Ongoing Work

We plan to share quantitative information from our data gathering and analytical efforts on completion of the project, so that the aggregated data compiled over the project duration could give us the necessary statistical significance for making robust correlations and conclusions. Individual cohort sizes being small, the data from each cohort does not provide sufficient sample size to allow for significant quantitative observations. The quantitative analysis of this investigation will be disseminated in engineering education forums as a companion report to this preliminary qualitative contribution.

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