Strategies to Recruit and Retain Students in Physical Sciences and Mathematics on a Diverse College Campus

By Jen-Mei Chang, Chuhee Kwon, Lora Stevens, and Paul Buonora

This article presents implementation details and findings of a National Science Foundation Scholarship in Science, Technology, Engineering, and Mathematics Program (S-STEM) consisting of many high-impact practices to recruit and retain students in the physical sciences and mathematics programs, particularly first-generation and underrepresented minority (URM) students. In particular, we discuss how the program uses three key strategies to improve persistence and retention in a STEM pipeline including access to financial resources, community building, and faculty mentorship at critical transitions. Although the rate of URM students within the general physical sciences and mathematics program on campus fluctuates at around 35%, this scholarship program recruits at a much higher rate of URM students at nearly 61%. Of the 44 students receiving support for at least one semester, 100% either graduated or continued with their original major, including students who discontinued from the program because of low GPA or lack of financial need. Among the program's positive outcomes, students experienced increased motivation for success and readiness for graduate studies or the workforce.

The President's Council of Advisors on Science and Technology (PCAST; 2012) projected that at least one million additional science, technology, engineering, and mathematics (STEM) degree graduates will be needed to sustain the current demands of the national workforce. A major contributing factor to the shortage in STEM workers is low student retention rates in college STEM degree programs. For instance, data from the 1995–1996 Beginning Postsecondary Students Longitudinal Study show that among all STEM entrants between 1995/1996 and 2001, 53% completed a STEM degree (including ones switching to a different STEM field). The remaining 47% either switched to a non-STEM field or left postsecondary education without earning any credential (Chen, 2009). Within communities traditionally underrepresented in the STEM fields, that is, Hispanic, African American, and Native American students, participation rates lag behind populations that are not underrepresented in the larger college community (Tables 1 and 2).

As shown in Table 1, approximately 2.3% and 2.6% of enrolled students intending to pursue degrees in mathematics and statistics and the physical sciences were identified as African American or Hispanic, respectively

TABLE 1

Data of the total enrollment of first-time, first-year undergraduate students at all institutions in 2010, sorted by ethnicity and majors (National Science Foundation, 2013).

	Mathematics and statistics	Physical sciences	All science and engineering	Total enrollment
African American	2,308	8,309	168,484	461,601
Hispanic	3,461	9,395	201,242	494,451
American Indian or Alaska Native	29	555	8,059	29,201
White	15,469	48,126	635,955	1,718,797
Asian or Pacific Islander	2,001	5,002	81,696	166,727
Other or unknown race or ethnicity	5,487	13,169	108,645	274,356
All ethnicity	28,755	84,555	1,204,081	3,145,133

Note: The numbers presented here are for U.S. citizens and permanent residents only. Here, physical sciences include degrees in chemistry, physics, and astronomy.

(National Science Foundation [NSF], 2013). Even more alarming is the percentage of underrepresented minorities (URM; in this article, URM refers to African American, Hispanic, Native American, Alaska Native, or U.S. Pacific Island Native students) who persisted to their originally intended degree. Table 2 shows the raw number of bachelor's degrees awarded to U.S. citizen and permanent residents in 2010 (NSF, 2013). Assuming the year-to-year variance in the number of people declaring science and engineering majors is small, and ignoring the number of students who switch in and out of a major, the data in the table suggest that roughly 29% of Hispanic students persisted to a degree in mathematics and statistics, while only 12% persisted in the physical sciences (defined by NSF as chemistry, physics, and astronomy).

Although the nation as a whole faces the task of recruiting and retaining URM students in STEM, each campus brings a unique set of challenges and potential to address the overall objective. On our large, highly diverse (Hispanic students made up roughly 35% of the entire student population in 2013), urban, and comprehensive state university, the data indicate a campus-wide urgency to recruit and retain URM students in the physical sciences and mathematics (PSM; Tables 3 and 4).

Within the College of Natural Science and Mathematics (CNSM), we reach 50% graduation among first-time freshmen (FTF) in 6 years and transfer students in 4 years. Table

TABLE 2

Data of the total number of bachelor's degrees awarded to U.S. citizen and permanent residents in 2010, sorted by fields and ethnicity (National Science Foundation, 2013).

	Earth, atmospheric, and ocean sciences	Mathematics and statistics	Physical sciences	All science and engineering	All degrees awarded
African American	97	834	1,088	43,428	152,404
Hispanic	246	1,005	1,161	46,336	147,205
American Indian or Alaska Native	44	76	108	3,624	11,485
White	3,879	11,173	11,931	326,643	1,082,145
Asian or Pacific Islander	158	1,630	2,117	50,367	109,022
Other or unknown race or ethnicity	274	1,106	1196	36,745	118,368
All ethnicity	4,698	15,824	17,601	507,143	1,620,629

Note: Physical sciences include degrees in chemistry, physics, and astronomy.

TABLE 3

Enrollment data of first-time freshmen (FTF) and transfer (TR) students admitted in 2006 at a western state campus where the scholarship program is implemented, sorted by ethnicity and majors.

	AA*		API		Caucasian		Hispanic*		NA*		Unknown		Non-U.S.		Total	
	FTF	TR	FTF	TR	FTF	TR	FTF	TR	FTF	TR	FTF	TR	FTF	TR	FTF	TR
Campus-wide	255	160	1118	662	1331	1239	1316	852	36	27	257	364	154	224	4467	3528
College-wide	35	13	141	86	101	82	102	51	1	2	26	29	13	17	424	280
Bio. Sciences	23	7	81	55	69	53	71	31	0	2	15	18	7	10	200	266
Chemistry and biochemistry	10	2	47	27	13	11	11	7	1	0	5	4	3	2	90	53
Mathematics and statistics	2	2	10	4	15	10	14	12	0	0	6	4	1	5	29	48
Physics and astronomy	0	1	2	0	4	1	5	3	0	0	0	1	2	0	13	3
Geological sciences	0	0	1	0	0	7	1	1	0	0	0	2	0	0	2	11

Note: AA = African American, API = Asian Pacific Islander, NA = Native American. *a classification of underrepresented minority students.

3 gives FTF and transfer student enrollment data for the 2006–2007 academic year (AY). However, the number of degrees awarded in 2012 (Table 4) tells an unfortunate story of lack of persistence among students majoring in STEM. Roughly 61% (151/249) of the students who originally declared majors in PSM failed to graduate with a degree in those fields within 6 years. Furthermore, Figure 1 indicates a consistent lack of retention within the college. Given that only 11% to 18% of URM students who declared majors in the college between 2003 and 2008 actually graduated with a CNSM major within 6 years, there is a clear need to design and implement programs to better support URM students in their pursuit of STEM degrees, especially on minority-serving campuses.

Many different approaches to improve retention have been studied (Hazari, Saddler, & Sonnert, 2013; Hurtado et al., 2007; Rasmussen & Ellis, 2013; Slovacek, Whittinghill, Flenoury, & Wiseman, 2012; Watkins & Mazur, 2013). For URM students, financial assistance in paying for college (Astin & Astin, 1992) and supporting "belonging" (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; Seymour & Hewitt, 2000) rank among the most significant factors that achieve success in STEM-related fields. Hence, for diverse campuses with large URM populations, emphasis should be placed on recruitment and retention of STEM students through financial support and community building. Not surprisingly, in a self-identified preprogram anonymous survey, over 55% of students indicated that financial issues posed a significant barrier to the completion of their majors. In addition, 77% and 67%, respectively, of the 154 valid responses indicated that research experiences and mentorship from faculty members would contribute greatly to students' success in the major. Furthermore, the survey indicated that a high fraction of students

FIGURE 1

Six-year graduation rate of first-time freshmen (FTF) who declared their major in the College of Natural Sciences and Mathematics (CNSM) in the indicated cohort year. For example, about 23.7% of FTF and 14.5% of underrepresented minority students who declared their major in the college in 2006 actually graduated with a major in the CNSM within 6 years.

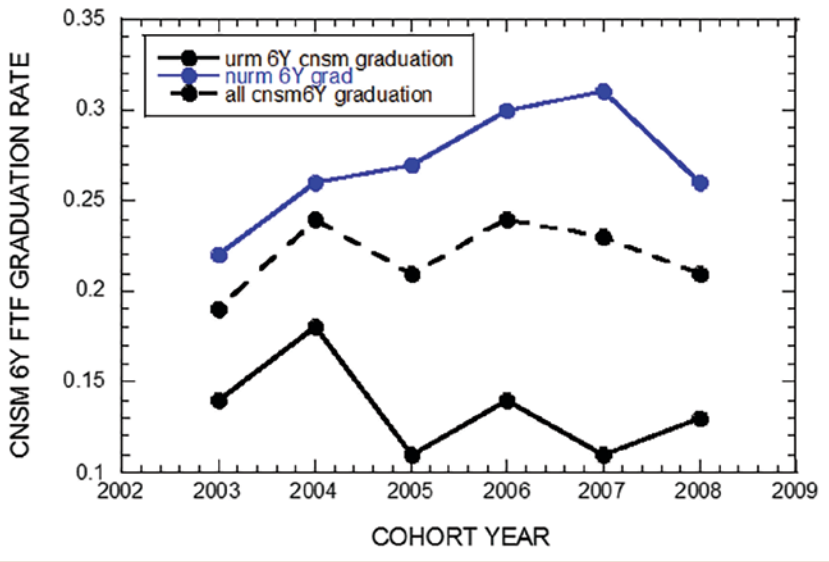


TABLE 4

Total number of bachelor of science degrees awarded in 2012 at a Western state campus where the scholarship program is implemented, sorted by ethnicity and majors.

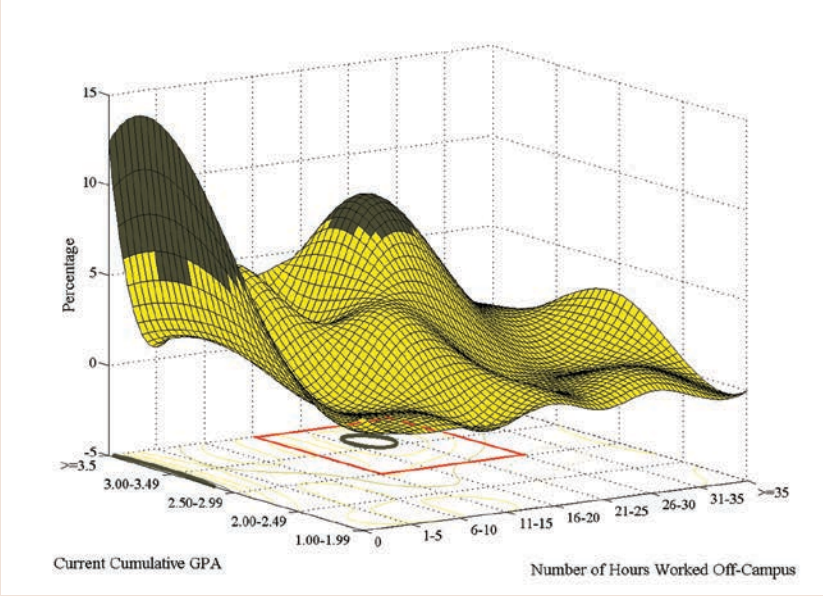
	Mathematics and statistics	Chemistry	Physics and astronomy	Geological sciences	Total by ethnicity
African American	0	0	0	1	1
Hispanic	9	7	0	0	16
American Indian or Alaska Native	2	0	0	0	2
White	15	8	3	3	29
Asian or Pacific Islander	6	26	2	0	34
Other or unknown race or ethnicity	7	4	1	0	12
Temporary resident	0	0	0	0	0
Total by degree program	41	47	6	4	98

work between 16 to 20 hours per week off campus, with cumulative GPAs between 3.0 and 3.5 (Figure 2). The scholarship program targeted these students who have demonstrated success while needing to work. Within this group, we look for students with strong motivation and hidden potential for advanced studies who might not be successful academically due to financial burden.

We designed the program to address the identified needs of our students while building a strong sense of belonging that can be essential to students in overcoming difficult periods in their major. The infrastructure used to recruit and retain students in physical sciences and mathematics programs on our diverse campus is outlined next. Measurement of success and the identification of necessary modifications are derived from evaluation data captured through individual and group interviews and effect surveys.

FIGURE 2

Percentage distribution of students' cumulative GPA versus number of hours worked per week off campus for 154 students surveyed in 2010 on the campus where the scholarship program is implemented.



Program overview

The Physical Sciences and Mathematics Scholarship program (PSMS) is funded by NSF between fall 2010 and spring 2015 and differs from many student development programs by not requiring participation in directed research. Instead, students are encouraged to explore and participate in activities shown to affect students' educational and career aspirations (Adedokun et al., 2012). The program combats obstacles to persistence through cohort camaraderie (Buch & Spaulding, 2008; Tinto, 1997), family and faculty support, peer mentoring, timely student advisement (Bahr, 2008; Graunke & Woosley, 2005; Lee, Olson, Locke, Michelson, & Odes, 2009; Osborne & Jones, 2011), and academic intervention. All of those strategies have been shown to improve retention of diverse students in higher education (Herzog, 2005).

The participants are divided into two subprograms: the Starters program for students in their early college career and the Scholars program for advanced students. This two-tier system is modeled on the structure of the National Institutes of Health–funded Research Initiative for Scientific Enrichment program on campus. Our scholarship offers a maximum of $6,400 a year to each qualified student. Table 5 provides a list of recommended and required activities for students at different tiers. Most of the required activities are designed to keep students connected with their peer participants and their discipline mentor to ensure they are supported through critical points of their educational pathway.

Participant description

Between the fall of the 2010–2011 AY and spring of the 2014–2015 AY, the program offered financial support to 44 students, of which 61% were URM students. Table 6 lists the number of scholarship students in each targeted discipline along with the number of URM awardees between fall 2010 and spring 2015. In general, students who are accepted into the program receive continuing support as long as they meet retention criteria. The length of support ranges from one to eight semesters, depending on the academic status of the students when they apply. A majority of the students participated in the program for two to five semesters (35/44), with one student receiving support for eight semesters.

Of the 44 students receiving support for at least one semester, 100% of them have either graduated or continued with their original major at the time this manuscript was written. The 100% retention rate applies even to those who were discontinued from the program. Among the 10 students who were discontinued, four were discontinued because of low GPA (below 2.5), three transferred to different enrichment programs or changed to a nonqualifying major (e.g., biochemistry), one no longer had financial need, one switched to a part-time status, and one did not

reapply to the program. Moreover, 78% (29 of 37) of the students participated in cocurricular activities, such as industry internships, summer or academic year research experiences, and summer enrichment programs. By spring 2014, 50% (10 of 20) of the PSMS students who graduated were URM students, whereas only 22% (22 of 100) of the students who graduated with a degree from the CNSM were URM students. Among the PSMS students who graduated, 60% (12 of 20) pursued a professional school or STEM graduate degree.

Recruitment and selection

The program is advertised through flyers and an official website. Each semester, the faculty mentors work with discipline advisers and through direct contact with students to solicit strong recommendations and applications. In addition, the program is advertised to the Starters in various orientation programs. Freshmen are informed about the program during mandatory advising and in their freshmen experience success course. Current participating students are invited to relevant classes to share the impact that the program has had on them. We have found that hav-

TABLE 5

Recommended and required activities for the participating students during the two stages of their academic path.

		Incoming year Fall	Incoming year Spring	Retained year Fall	Retained year Spring
Starters	Course work	Calculus I, General Chemistry Part I	Calculus II, General Chemistry Part II, Mechanics and Heat	Calculus III, Electricity and Magnetism	General Biology
	Required activity	Participate at least one hour per week in group study or peer-tutoring sessions. Attend two endorsed workshops, conferences, or academic events per semester. Attend the annual and monthly gatherings. Participate in an annual interview. Participate in the summer workshop to develop curriculum vitae, personal statements, and cover letters.			
	Recommended activity	Attend all group study and peer-tutoring sessions organized by the program. Get tutoring help for both science and nonscience classes. Get involved with the student clubs.		Apply for the Scholars' program. Apply for on-campus research programs. Apply for internships or REU programs. Apply for on-campus major-related positions such as tutor and supplemental instructor.	
Scholars	Course work	Each student may have different courses depending on the major. Students are advised to take the same GE classes to finish all remaining requirements.			
	Required activity	Meet once a month with the faculty advisor from the declared major. Attend two endorsed workshops, conferences, or academic events per semester. Volunteer a minimum of 50 hours during the academic year for research, tutoring, or peer mentoring. Attend the annual and monthly gatherings. Participate in an annual interview. Participate in the summer workshop to develop curriculum vitae, personal statements, and cover letters.			
	Recommended activity	Apply for internships or REU programs. Apply for on-campus research programs. Apply for on-campus major-related positions such as tutor and supplemental instructor. Register in the campus Job Board at the Career Development Center.		Apply for graduate schools or jobs.	

Note: REU = research experiences for undergraduates; GE = general education.

ing peers share personal stories with the incoming students is effective in encouraging students to apply. The Scholars program is advertised in the enrollment orientation for the transfer students and by recruiting the existing Starters and students who are ready to take discipline-specific upper division courses. Table 7 gives a detailed description of the minimum selection and retention criteria.

The evaluation of applications involves a two-step process. First, each faculty mentor interviews the applicants in their discipline for professionalism, motivation, communication, and ability to manage time and resources. Then highly qualified candidates are invited to a 15-minute panel interview with the entire steering committee. The steering committee collectively makes the final selection, with no one department having more than two first-year recipients for each subprogram. We have found that the panel interview helps both the faculty and the students communicate expectations. Not only can we gauge the scholastic potential of applicants during these conversations, but the entire process serves as an excellent practice for the students and helps them assess their own readiness for challenging situations.

Activities

To reduce duplication, the program uses many successful aspects of existing programs on campus, such as workshops on resume writing, interview skills, and job search offered by the Career Development Center. The program also offers financial support to help students attend regional and national conferences. To engage the families of PSMS students in their academic program and career development, an annual family-and-friends dinner is hosted on campus during the fall semester. Recognizing the accomplishments of our scholarship students is important, but it is equally vital to acknowledge family support as students, especially first-generation students, pursue their degrees.

Additional activities, such as the spring student–faculty potluck, are organized to encourage students' sense of identity as scientists and promote a feeling of belonging. Students from different cohorts and disciplines routinely interact, sharing their learning experiences through monthly brown bag socials hosted by the faculty advisors. The advisors also check in with students monthly to discuss academ-

TABLE 6

Number of student awardees along with the number of underrepresented minority student awardees in each of the four targeted disciplines between fall 2010 and spring 2015.

	Total awardees	Program URM	Program URM rate (%)	Discipline URM rate (%)
Mathematics	11 (1: g)	9 (1)	82	37
Chemistry	10 (2: fn, m)	2 (1: m)	20	24
Physics	11 (4: 2g, 2s)	10 (4)	91	49
Geology	12 (3: g, f, rp)	6 (2: g, rp)	50	35
Overall	44	27	61	35

Note: The total number of students who stop receiving the scholarship at some point because of various reasons is given in parentheses. Reasons include a change in major (m) or full-time status (f), a switch to a different scholarship program (s), low GPA (g), a lack of financial need (fn), and a failure to reapply to the program (rp). URM = underrepresented minority.

TABLE 7

Program's minimum selection and retention criteria.

Selection criteria	
1	Be enrolled full time and seeking a BS degree in one of the four targeted disciplines.
2	Be a U.S. citizen or permanent resident.
3	Be eligible for need-based federal financial aid.
4	Have a minimum GPA of 2.5.
5	Agree to provide tracking data and be part of a longitudinal research and tracking of graduate studies or professional placement.
6	Be eligible or making successful progress toward your eligibility to take upper division courses set by each degree program.
Retention criteria	
1	The semester GPA while in the program must be higher than 2.5.
2	The recipient must demonstrate appropriate academic progress in the degree program.
3	The recipient must have participated in the required minimum number of the endorsed activities/workshops by the program.
4	The recipient must be eligible for the need-based federal financial aid. The eligibility will be verified each semester.
5	The recipient must demonstrate their intention to obtain the intended BS degree.

ics and to help students stay focused on their goals. The PSMS program offers an annual summer workshop where students work side-by-side in developing personal statements, cover letters, curricula vitae, and other application materials for academic programs and internships, through iterative revising. Many students have successfully applied to graduate schools and summer REUs (Research Experiences for Undergraduates) following the workshop. This workshop and the fall family-and-friends dinner have the most impact on students' confidence.

Findings

The following findings are based on data that came from two instruments: annual focus group interviews and an informal program evaluation survey. Psychology student evaluators, working under the supervision of the program evaluator, conduct these interviews. The anonymous evaluation survey was conducted during 2013–2014 AY as an alternative instrument to capture the program's long-term effect through anecdotal and numerical responses. The questions were designed to measure the efficacy of a learning community in cohort development and collaborative learning and to evaluate the effectiveness of various aspects of the program.

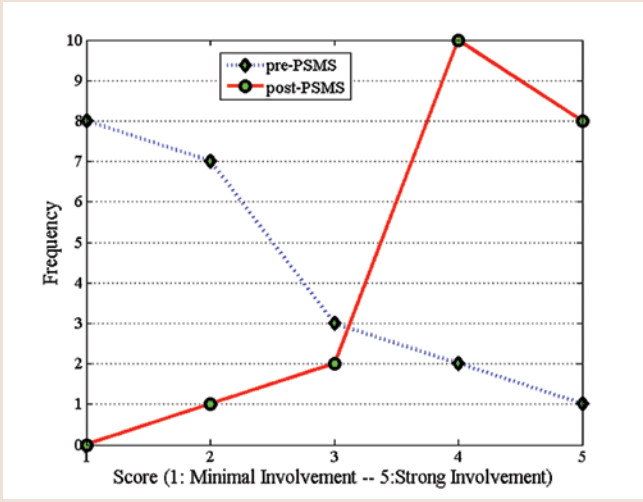
As previously noted, financial support plays a critical role in the degree to which URM students participate and succeed in college (Hurtado, Newman, Tran, & Chang, 2010). In fact, 16 of the 21 students (76 %) who responded to the survey mentioned that money was a major factor that helped to enhance their overall success in the major. Sixteen of 21 also mentioned that mentorship received from the program's faculty advisers helped them to stay on track for graduation, prepare them for graduate school, and carried them through obstacles both in and outside of school. Half of the students who responded also indicated that being in a learning community and interacting with fellow scholarship students helped them persist through their studies.

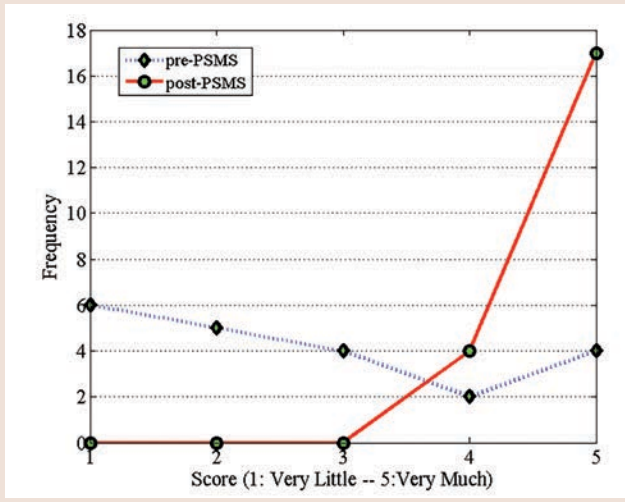
It is not a coincidence that the number of nonprogram activities students participated in on campus after they entered the scholarship program increased drastically (Figure 3). Some activities included taking major leadership roles in student organizations, becoming discipline mentors for incoming freshmen and fellow junior students, participating in the Lois J. Swanson National Leadership Academy (a program aimed toward developing community leaders on campus through workshops and community service), becoming a supplemental instructor for a class in their major, participation in research competitions (e.g., Mathematical Modeling Contest and undergraduate research symposia), performing academic research in labs, and attending conferences and presenting research work at national meetings. As a result of these activities, students have experienced elevated confidence level in their abilities to enter graduate programs, professional schools, or industry positions.

All students reported that they considered applying to graduate or professional schools after they entered the scholarship program in contrast to 52% (11 of 21) who reported having

FIGURE 3

Left: A frequency plot of 21 students' numerical responses to the question: How much were you involved in campus activities before/after entering the scholarship program? Scale metric: *minimal involvement* = 1, *strong involvement* = 5. Right: A frequency plot of 21 students' numerical responses to the question: How much did you consider applying to graduate or professional school before/after entering the scholarship program? Scale metric: *very little* = 1, *very much* = 5.





considered *very little* or *somewhat* in pursuing an advanced degree before entering the program (Figure 3). Moreover, 76% (16 of 21) reported that they feel *very much* that their participation in the PSMS program prepared them for graduate studies and/or industry positions when they graduate.

Students reported in the survey that they have (a) learned to compose letters of intent to academic programs and conferences as a result of the program's weeklong summer workshop, (b) increased their awareness of other funding/research opportunities that are available to aid them through their studies, (c) acquired "survival skills" (e.g., time management, networking, and creating supportive communities) to combat challenges during their education pathway, (d) gained a fresher perspective on job prospects outside of academia, and (e) attended research conferences to stay current with their research interests or attended educational workshops that provide information on graduate school applications and networking opportunities.

All students agreed that the annual family-and-friends mixer allows the family members to better understand the amount of work required to succeed in a STEM major. This event has proven particularly helpful for families with first-generation college students because it gives parents a perspective on how demanding STEM degrees can be, as illustrated by two student quotes:

> My mother pressured me to work and felt that I spent too much time in school and that it was a waste. After the PSMS dinner, her eyes were opened and she saw how important higher education is and began to understand why I spent so much time at school. After hearing the accomplishments of the other students, she wanted me to become more involved with school. She was amazed at the accomplishments the students had achieved all while studying for a degree. The dinner was the sole reason my mother was able to see what I had been achieving in school and why she began to support my dream of earning a degree.

> My family had the opportunity to interact with the parents of other scholars and they realized how much we all study. They didn't know how involved we were in school activities until the dinner and they were very proud of me and my accomplishments.

The responses from multiple annual interviews indicate that the program's impact expanded beyond its original goals. Students felt honored to be selected for the program and intrinsically wanted to succeed in their studies instead of just getting through. The scholarship program improved students' confidence level among their peers. Having a close social network with other students also made the Scholars realize that there are students in similar positions, which indirectly increased their participation in classes. Many students became leaders of their discipline community by initiating study groups and offering voluntary help to their fellow students.

Summary and conclusion

In this article, we presented a scholarship program that consists of many high-impact practices to recruit and retain students, particularly first-generation and underrepresented minorities, in the physical sciences and mathematics disciplines. Hopefully, these findings serve as a blueprint to schools and funding agencies when designing programs to help students persist through the STEM pipeline. Our model revolves around two well-established factors in achieving a high retention rate in STEM-related fields—financial assistance in paying for college and feeling of belonging. These are accomplished through scholarship, community building, and faculty mentorship.

The program provides a supportive academic environment that immerses participants in the academic community, enabling them to reach their scholastic potential. Interactions with faculty provide scholarship recipients with increased confidence, seen through more active participation in and outside of classrooms, as well as comfort in assuming leadership positions. Furthermore, the interaction with other students in similar situations creates a sense of community and belonging that transcends the discipline boundaries and leads to increased motivation in course work. Consequently, retention rates within the targeted disciplines improved, particularly in the URM student population.

Perhaps the most crucial yet challenging aspect of the program has been recruitment. Through annual interviews and informal conversations with students, we discovered that students did not apply because of fear of rejection, a reaction more common among first-generation students. We often get the response "If I don't apply, then I won't be rejected" from students who qualify but fail to apply. Our selection metric has evolved significantly over time from choosing students who are in great financial distress but with the minimum GPA requirement to choosing students with a higher GPA but in great need of mentorship. We have learned that students with lower GPAs often have a multitude of obstacles preventing them from being successful academically, many of which cannot be mitigated through monetary support. We are reminded that the ultimate goal of the program is to improve retention and persistence. To maximize the impact of the program, we suggest

selecting students with strong motivations and assessing applicants for hidden potential during interviews. ■

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Jen-Mei Chang (jen-mei.chang@csulb.edu) *is an associate professor in the Department of Mathematics and Statistics,* ***Chuhee Kwon*** *is a professor in the Department of Physics and Astronomy,* ***Lora Stevens*** *is an associate professor in the Department of Geological Sciences, and* ***Paul Buonora*** *is a professor in the Department of Chemistry and Biochemistry, all at California State University, Long Beach.*