Identifying NSF S-STEM-Sponsored Program Activities that have a Positive Impact on Mechanical Engineering S-STEM Scholars

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Abstract

Due to current needs for a diverse and skilled workforce in engineering, the NSF-sponsored Mechanical Engineering (ME) S-STEM Scholarship Program in our institution has provided enhanced educational opportunities to more than 110 economically disadvantaged and academically talented undergraduate students in the Mechanical Engineering Department from 2009 to the present. The NSF funded S-STEM project focuses resources on financial support, coupled with curricular and co-curricular activities designed to facilitate student degree attainment, career development, employability in STEM-related jobs, and enrollment in graduate school. In addition, our S-STEM program proactively implements engineering research activities, including in-depth lab tours, seminars, REUs, research conference support, featuring research/internship on our website, and presentations to recruit students for research, etc.

In this study, we present preliminary data that reveal the attitudes and perceptions of the current 25 ME S-STEM scholars based on surveys conducted recently. The scholars were asked to provide their opinion on the impact that the activities sponsored by our S-STEM program had on their attitudes and perceptions. Results demonstrated that faculty and peer mentoring are the most effective methods contributing to positive attitudes and perceptions. In addition, internship opportunities and research-related activities such as lab visits, REUs, research seminars, and attending research conferences, are viewed favorably by the scholars in helping them establish their science/engineering self-efficacy and engineering identity, and understand their expectations and goals. In addition to mentoring, community building activities such as program retreats, social events, and being part of a professional society were considered helpful and contributed to integrating into campus life and improving their sense of belonging to the campus and program. In June 2019, all but two scholars were retained in our scholarship program; those who remained in the program consider all S-STEM activities favorable to their retention. Among the 10 scholars who graduated from the ME undergraduate program in the past year, 40% of them stated that they will pursue a graduate degree, 20% will work in industry, and the other 40% will work in industry and enroll in a graduate school as a part-time student. Those 10 scholars identified faculty and peer mentoring, all of the research related activities sponsored by our program, internships, and social interaction with faculty and their peers as positive factors that helped them make their decisions.

Introduction

Nationally the STEM industries in the United States face a looming retirement cliff as skilled baby boomers begin to retire and leave the workforce [1]. With the continuous increase in demand for the STEM jobs, it requires highly qualified STEM professionals to fill those positions to maintain its competitive edge. Improvements in student retention and graduation rates by providing them with a robust college STEM education are essential to meet the demands of regional and national employers.

The Mechanical Engineering (ME) S-STEM Scholarship Program in our institution was established to provide enhanced educational opportunities to undergraduate students in the ME department. The selected students receive scholarships and supplemental program activities to facilitate their full-time enrollment to improve scholastic achievement, leading to industrial job placements and/or graduate school enrollments. The S-STEM scholars are connected to individual faculty mentors and provided with placement and understanding of internships and research experiences, in addition to monetary support. Incorporating research experiences into the education curriculum is a strength of our program [2-4]. Specific activities include research seminars emphasizing bioengineering, in depth laboratory visits, featuring scholars' research on our website, sponsoring their conference attendance, and offering research opportunity in the summer or semester. The research experiences have helped attract more female and minority students to mechanical engineering, expand scholars' skill base, and provide successful paths for graduate study [5-11]. Another successful component of the program is on community building tailored for commuting students, including an annual retreat, lunch with faculty members, workshops providing academic and professional development support.

Since its inception in 2009, the program has supported more than 110 undergraduate students with diverse ethical and economic backgrounds. The program has achieved a retention rate of 89% in the ME program. Among the 75 ME-STEM scholars who graduated, 32% are pursuing graduate degrees in an STEM major, 64% are now working in an STEM industry, and 4% are looking for job opportunity. The much higher retention rate and percentage of students pursuing graduate school suggest positive impacts of our program activities on our scholars. It is important to identify effective practices sponsored by our program so that the practice would be disseminated to other engineering programs in the country.

In this study, we present preliminary data that reveal the attitudes and perceptions of the current 25 ME S-STEM scholars based on surveys conducted in 2019. The scholars were asked to provide their opinion on the impact that the activities sponsored by our S-STEM program had on their attitudes and perceptions.

Methods

In partnership with the psychology department in our institution, a survey was developed and it contained measurable items regarding their attitudes, perspectives, science/engineering identity, and research self-efficacy. The first section of the survey consisted of 10 questions focusing on students' demographic information. The second section contained Likert scaled items to include "Research Self-Efficacy" (9 questions), "Science/Engineering Identity" (5 questions), "Expectations and Goals" (4 questions), "Academic Integration" (5 questions), and "Senses of Belonging to Program and Campus (8 questions)". The following describes development of the questions in each category.

Research Self-Efficacy: It is measured by items from the Scientific Self-Efficacy Scale [12-13] that assesses students' ability to function as a scientist/engineer. Sample items include

"use technical science skills", "generate a research question", and "use scientific literature and/or reports to guide research and develop theories."

Science/Engineering Identity: Scientific identity will be measured by the items from the Scientific Identity Scale [12-13] 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/engineers", "feel like I belong in the field of science/engineering", and "have come to think of myself as a scientist/engineer."

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. Sample statements include "confident that I will achieve my career goals", "excited about the idea of scientific research," "confident that I will achieve my academic goals", and "comfortable going to ME faculty and staff if I have a problem."

Academic Integration: Measured by items from the Your First College Year survey conducted by the Higher Education Research Institute at UCLA [14]. Sample items include "understand what your professors expect of you academically," "adjust to the academic demands of college," "manage your time effectively," and "develop close friendships with other students."

Sense of Belonging to the Program and to Campus: The items in this construct was adapted from the Sense of Community Index, which was developed based on McMillan and Chavis's theory of psychological sense of belonging [15-16]. Sample items include "I can trust people in the program", "I expect to be a part of the program for a long time, "I feel comfortable on campus" and "My College is supportive of me."

Following each category, the students were asked to check any activities they felt that contributed positively to each category. In Table 1, the 15 activities are placed into four groups including "Mentoring", "Academic help", "Research", and "Community Building". Note that all except the "regular faculty/staff mentoring" are extra activities initiated and/or promoted by the ME S-STEM program.

Typically, all ME undergraduate students receive advisement by staff members in the Dean's office during the 1st year and later by a faculty member in ME. Undergraduate students may talk to their advisor once a semester to get clearance on their registration for the next semester. "Extra faculty mentoring" refers to the mentoring from a faculty mentor assigned to each scholar in our scholarship program. The ME S-STEM scholars are encouraged to meet their faculty mentors when needed to discuss not only their academic progress, but also their future career plan and personal issues. Most of the scholars had talked to their faculty mentors more than three times each semester, suggesting that they felt comfortable to discuss issues they had with the faculty. "Peer mentoring" is a departmental program open to all the undergraduate students. The ME S-STEM scholars are required to join in this program and serve as either a "mentor" or a "mentee".

The ME S-STEM program also provides academic help to our students via organizing workshops on time management and tutoring service to our scholars. The faculty in our program actively encourage our scholars to pursue internship opportunity via connecting them to employers in industry and/or resources on campus. Various research related activities are implemented in our program, as shown in Table 1. Considering that most of the undergraduate students on our campus are commuters, we implemented many community building activities to promote interaction among the scholars and with their faculty mentors. We have our annual retreat, social events such as lunch with faculty, and workshops to create opportunity to promote gathering. All our scholars are also encouraged to join professional societies to interact with

their peers. With the support of the ME Department, a room in our Engineering building is used for scholars to use during the day time when they are on campus.

Table 1. Fifteen extra activities provided to scholars in the ME S-STEM Program

Group	Mentoring				
1	regular faculty/staff mentoring	peer mentoring	extra faculty mentoring		
	Academic Help				
2	workshop on time management	extra tutoring of courses	Internship		
	Research				
3	lab visit	attending research seminars	doing research in labs	attending research conference	feature your research/internship on website
	Community Building				
4	Annual retreat	social events such as lunch with faculty/students	workshop on graduate school application	part of a professional society such as ASME, SAMPI, SWE, etc	

The last section of the survey includes questions to measure students' retention and graduation. If the students were not going to graduate from the ME program, they were asked whether they would continue in the ME program. If the students would graduate after that semester, they were asked whether they planned to work in STEM industries and/or enroll in graduate school. Finally they were asked to check any activities listed in Table 1 that positively contributed to their retention or decision after their graduation.

The data collected in this study were numerically coded at a scale from 0 to 100, with 100 indicating the most positive level of variables being measured, i.e., "Absolutely Confident" or "Strongly Agree" or "Very Easy", as shown in Table 2. Any activity clicked by student would be counted as 1, then the percentage of the total number of clicks to the total number of the surveys would be an indication of how this activity positively contributes to individual categories or decisions.

Table 2. Scores assigned to individual measures

	Not at all confident	Somewhat confident	Moderately confident	Very confident	Absolutely confident
Research Self-efficacy	20	40	60	80	100
	Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly Agree**
Science/Engineering Identity	20	40	60	80	100
Expectations and Goals	20	40	60	80	100
	Very difficult	**Somewhat difficult**	**Somewhat easy**	**Very easy**	
Academic Integration	25	50	75	100	
	Very dissatisfied	**Dissatisfied**	**Neutral**	**Satisfied**	**Very satisfied**
Senses of Belongings	20	40	60	80	100

Results and Discussion

        A total of 25 validated surveys were completed and assessed. Among them, 8 (32%) were originally transferred from a local community college, 40% are female students, and 40% are URMs (Black and Hispanic). Students from all class standings, including freshmen (8%), sophomores (16%), juniors (20%), and seniors (56%) in the ME department, participated in the survey.

        As show in Figure 1, both scores in "Academic Integration" and "Research Self-efficacy" are below 80 over a scale of 100 (Table 2). A score of 67 in "Academic Integration" suggests that by average students feel academic integration is between "somewhat difficult" and "somewhat easy". The next low score of 70.8 is in achieving "Research Self-Efficacy. Students feel more than "moderately confident" but less than "very confident" in achieving "Research Self-Efficacy". Students agree that being an engineer/scientist is part of who they are in "Science/Engineering Identify" with a score of 86.1. They also agree that they understand the expectations and goals (score = 85.2) and they are satisfied with their senses of belonging to both the campus and program (score =86.6).
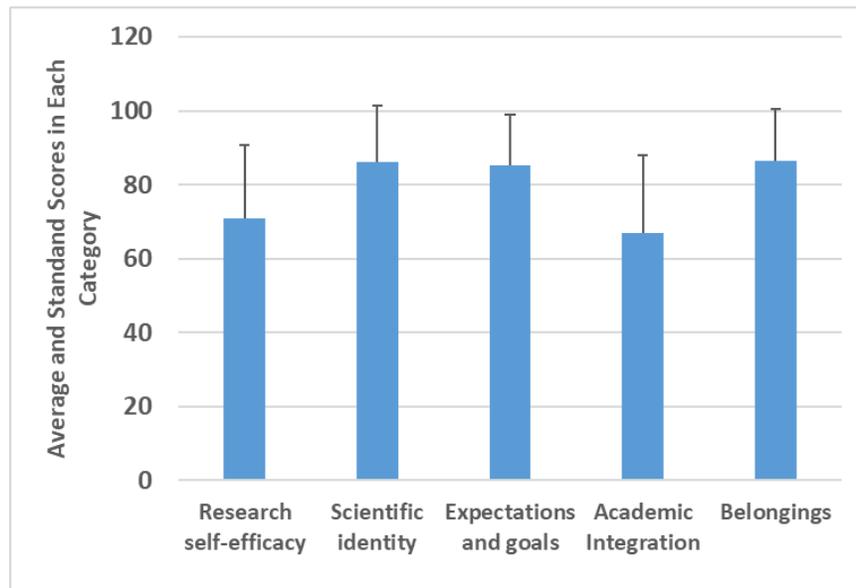

Figure 1. Average and standard scores in the five categories.

        Figure 2 gives the scores of individual mentoring activities that have contributed positively to the five categories. Not surprisingly, regulars mentoring by the faculty/staff assigned to the student is viewed by the students with the most positive impact. The other two mentoring activities, i.e., peer mentoring and extra faculty mentoring from the ME S-STEM Scholarship Program are also considered important. Approximately half of the scholars consider peer mentoring as having positive impacts. The extra faculty mentoring provided by the ME S-STEM Scholarship Program has the most impact on the category of helping our scholar in gaining scientific/engineering identity.
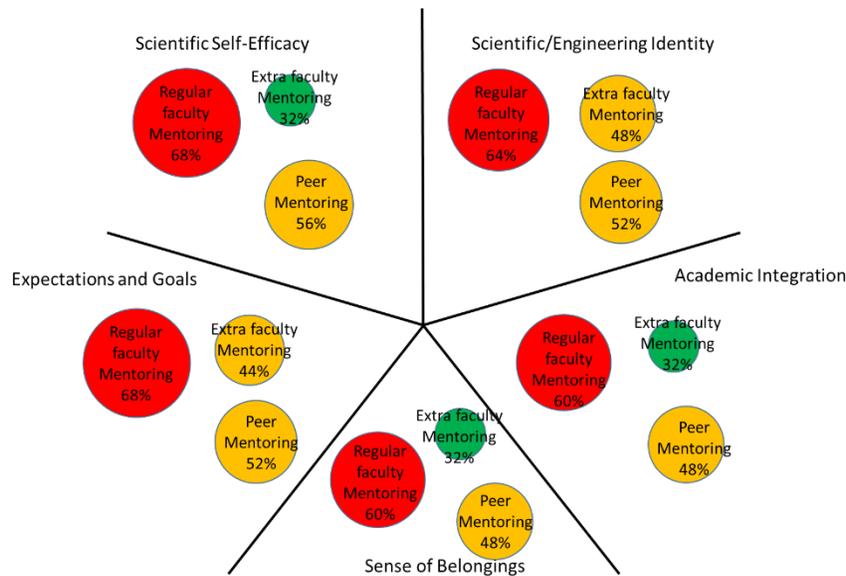
Figure 2. Percentages of individual mentoring activities having contributed positively to the five categories.

As shown in Figures 2-4, fewer scholars select the activities in the other three groups (Academic Help, Research, and Community Building) as having contributed positively to the five categories. In the three activities in "Academic Help", having an "Internship" is considered helping students gain ability to function as engineers, understand their expectations and goals, and identify themselves as engineers. Time management workshop is also considered as an effective activity, however, tutoring seems not as important as the other two activities.
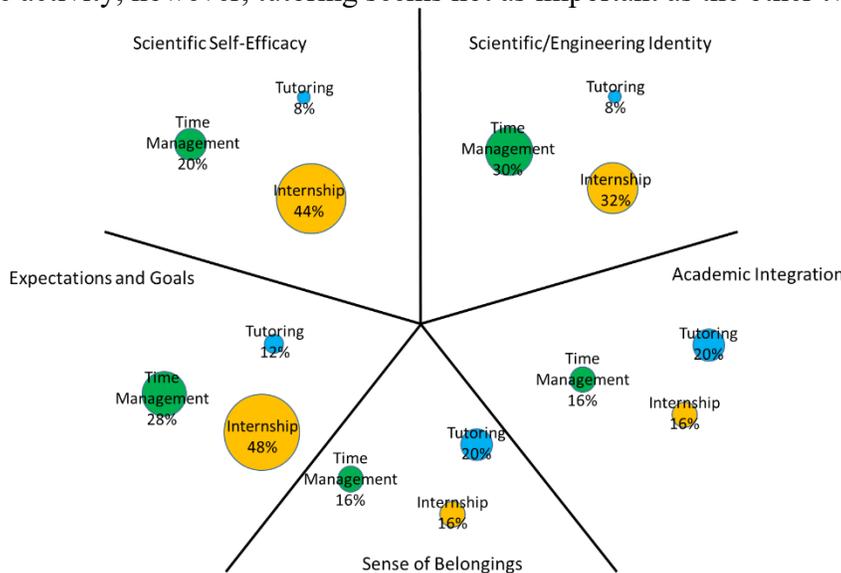

Figure 3. Percentages of individual academic help activities having contributed positively to the five categories.

The ME-STEM Scholarship Program has implemented quite a few activities related to research. As shown in Figure 4, the program organized in-depth lab visits, research seminars, and research experience for undergraduate (REU) opportunities provided to scholars have the

most impact, especially in "Scientific Self-Efficacy", "Science/Engineering Identity" and "Expectations". Less than 16% of the scholars consider attending conferences or featuring their research on website as having a positive impact. The lower percentages in those two activities may also reflect that not all the scholars have the opportunities to attend a research conference or do research, also have research results featured on website.
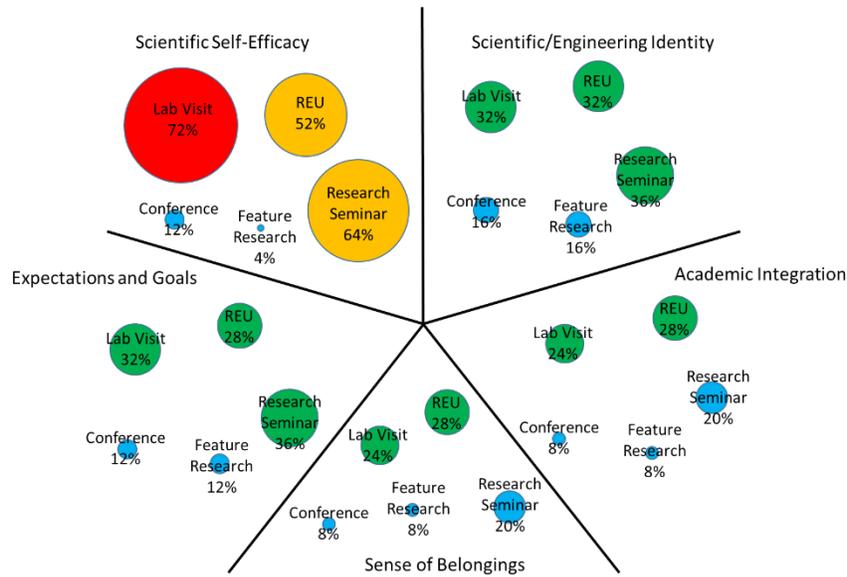

Figure 4. Percentages of individual research activities having contributed positively to the five categories.

The five community building activities have contributed more in helping students integrate into the program and campus. Illustrated in Figure 5, it is evident that having lunch with faculty and other students has the most impact. This may reflect similar attitudes of students on mentoring. Although in theory ME students should be aware of applying for student membership of a professional society (ASME, SWE, NSBE, etc.), it is not clear to us how many ME undergraduate students actually are members of those professional socieites. Nevertheless, based on the surveys, joining a professional society is considered as also a very important activity to connect with other students ("Academic Integration" and "Belonging").
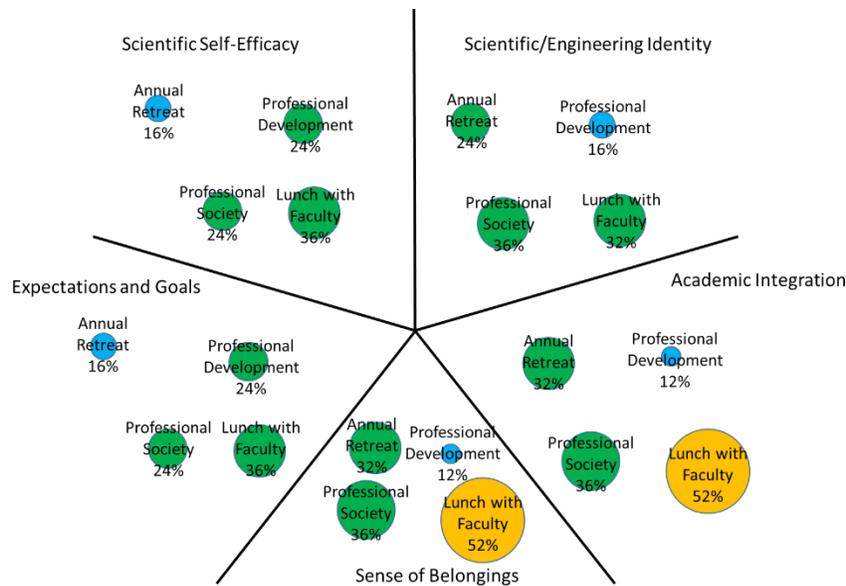
Figure 5. Percentages of individual community building activities having contributed positively to the five categories.

10 of the 25 scholars stated that they would graduate after the semester, and the rest 13 would continue in the ME S-STEM program. 2 scholars would leave the ME S-STEM program due to either low GPAs or transferring to another institution. Figures 6 and 7 gives the activities they consider having contributed positively to their retention in the ME program or graduation from the ME program, respectively. It is not a surprise again to see mentoring activities have the most impact, followed by internship and some research activities. Among the 10 scholars who would graduate from the ME undergraduate program in the past year, 40% of them stated that they would pursue a graduate degree, 20% will work in industry, and the other 40% would work in industry and enroll in a graduate school as a part-time student. According to the ASEE data of students in engineering [17], in 2017 more than 30,000 BS degrees in Mechanical Engineering were awarded, and almost 10,000 MS and PhD degrees are awarded in Mechanical Engineering in the United States. If one excludes the 70% international students in graduate degree programs who received their undergraduate education outside of the USA, a rough estimate shows approximately only 10% of the mechanical engineering BS graduates pursue graduate MS or PhD degrees. In our department, the percentage to enroll in a graduate school after their BS degree is typically very low (~10-15%) due to the high demands of engineers by local/national industry. As shown by the surveys of this study, the percentage of the scholars pursuing graduate degree in our ME S-STEM program is much higher than that of regular ME students in the department. The surveys have illustrated that community building activities such as lunch with faculty, professional development on graduate school applications, and joining a professional society contribute positively to their graduation decision, in additional to mentoring.
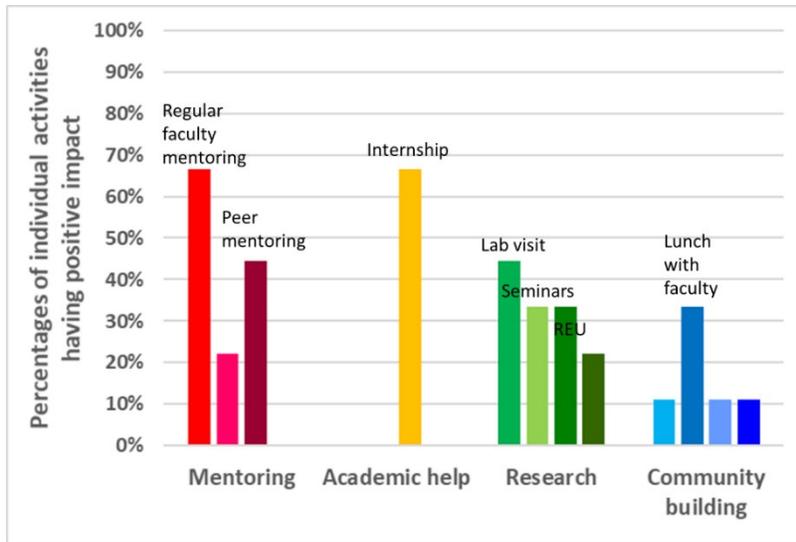
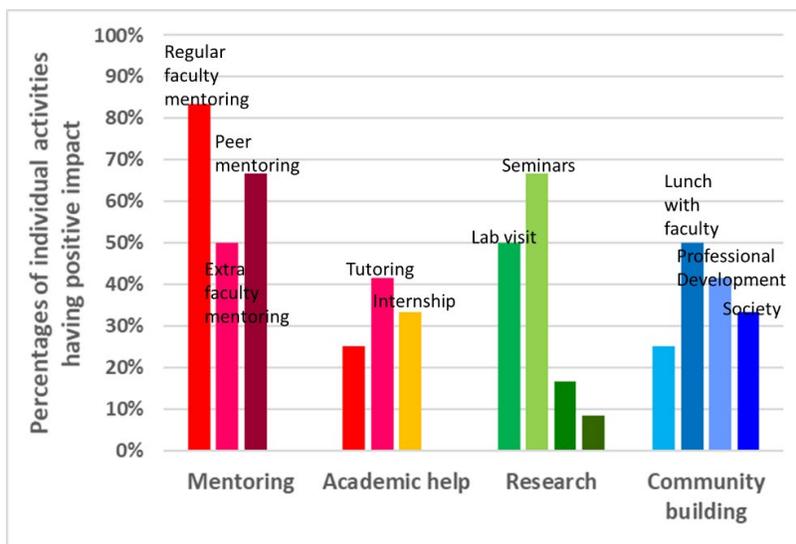**Figure 6. Percentages of individual activities having positive impacts to students' retention in the ME program.**

Figure 7. Percentages of individual activities having positive impacts to students' graduation in the ME program.

Conclusions

In this study, we present preliminary data that reveal the attitudes and perceptions of the current 25 ME S-STEM scholars based on surveys conducted recently. Further improvements are needed to help students in achieving scientific efficacy and academic integration into the program. The scholars were asked to provide their opinions on the impact that the activities sponsored by our S-STEM program had on their attitudes and perceptions. Results demonstrated that faculty and peer mentoring are the most effective methods contributing to positive attitudes and perceptions. In addition, research-related activities such as lab visits, REUs, research seminars, attending research conferences, and internship opportunities are viewed favorably by the scholars in helping them establish their science/engineering self-efficacy and engineering identity, and understand their expectations and goals. In addition to mentoring, community

building activities such as program retreats, social events, and being part of a professional society were considered helpful and contributed to integrating into campus life and improving their sense of belonging to the campus and program. In June 2019, all but two scholars were retained in our scholarship program; those who remained in the program consider all S-STEM activities favorable to their retention. Among the 10 scholars who graduated from the ME undergraduate program in the past year, 40% of them stated that they will pursue a graduate degree, 20% will work in industry, and the other 40% will work in industry and enroll in a graduate school as a part-time student. Those 10 scholars identified faculty and peer mentoring, all of the research related activities sponsored by our program, internships, and social interaction with faculty and their peers as positive factors that helped them make their decisions.

Acknowledgement

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