An S-STEM Project for Improving Undergraduate Engineering Education

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Introduction

As technology increasingly impacts the nation's economy and security, high demands have been set for engineering schools to graduate an ever greater number of quality students optimally educated to meet business and industry needs. However, recent statistics compiled by the ASEE reveals that engineering graduation and retention rates at U.S. universities are not keeping up with the nation's increasing demands for engineering talent [1]. In 2000, less than 5% of all undergraduate degrees were awarded to engineers. Engineering bachelor's degrees have grown only 1% since 2005 [2].

To address the needs for a high quality science, technology, engineering, and mathematics (STEM) workforce in STEM disciplines, the National Science Foundation has established a Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program [3]. The program provides "scholarships for low-income, academically talented students with demonstrated financial need who are pursuing associate, baccalaureate, or graduate degrees in STEM" and supports "the adaptation, implementation, and study of effective evidence-based curricular and co-curricular activities" [3].

Since the inception of S-STEM program, universities and colleges across the country have received support from this program through a competitive process [4-8]. The literature shows that the S-STEM program has generated positive impacts in undergraduate STEM education [4-8]. For example, Kalevitch et al. created a Living-Learning Cohort model for the S-STEM students at their university [6]. As a result, their S-STEM students "consistently outperformed their peers every semester," and on average, the S-STEM students' academic performance "was equivalent to a B+ as compared to a B of their peers" [6]. Medsker et al. conducted an experimental study on the impact of the S-STEM program on student outcomes [7]. Based on relevant retention and graduation data collected in their study, they found that unmet financial needs play a significant role in student retention and when mitigated, led to enhanced academic success [7].

Our project was funded in 2015 by the NSF S-STEM program. The project has two goals. The first goal is to provide S-STEM scholarship support for academically-talented, financially-needy undergraduate students in two engineering departments at our university. These two engineering departments include the Department of Mechanical & Aerospace Engineering (MAE) and the Department of Civil & Environmental Engineering (CEE). Each S-STEM student is provided a scholarship of $5,000 per year for up to four years. The second goal of our project is to train these S-STEM students to become effective scientific and technological contributors when entering the engineering workforce. The project involves close collaboration among faculty and staff members in three departments (MAE, CEE, and the Department of Engineering Education) and the College of Engineering Advising Office.

This executive summary describes several representative project activities we have implemented since the start of the project. The results of assessing the effectiveness of each project activity are presented. The experiences gained are also described throughout this executive summary.

Student recruitment and number of S-STEM scholarships awarded

Students were recruited primarily through email flyers and classroom visits. We found that classroom visits were more effective than email flyers because classroom visits provided students an opportunity to interact with us and get their questions answered. Students submitted their applications online, which included their resumes, statements of career goals, transcripts, and other documents. A six-member Selection Committee was formed to review all student applications. The Committee also worked closely with our university's Financial Aid Office and obtained the information of unmet financial needs of each student applicant. The Committee selected student awardees based on a comprehensive consideration of an applicant's unmet financial needs and academic performance.

Since the start of the project in 2015, we have awarded S-STEM scholarships to 12 students in Year 1 of the project, 26 students (including 12 Year-1 students and 14 new students) in Year 2, and 26 students (including 21 Year-2 students and 5 new students) in Year 3. The success rate for new student applicants are 27% in Year 1, 13% in Year 2, and 14% in Year 3. Among 26 students in Year 2, four students successfully graduated and hence did not apply for the renewal of their scholarships in Year 3. All four of these students have secured industrial employment.

As two examples, Figs. 1 and 2 show, respectively, the unmet financial need and the incoming graduate point average (GPA) of S-STEM students in Year 3. The average unmet financial need is $20,182, and the average incoming GPA is 3.69 for these S-STEM students.

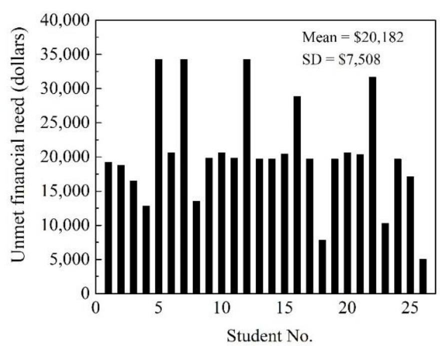

Figure 1. Unmet financial need of the S-STEM students in Year 3

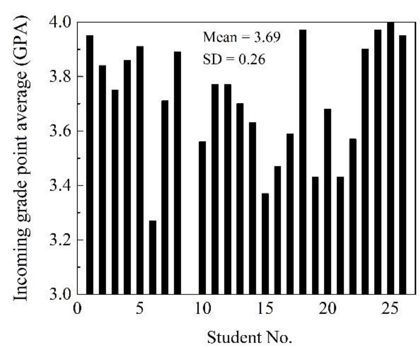

Figure 2. Incoming GPA of the S-STEM students in Year 3

Seminars by industry professionals

We have invited six guest speakers from industry to deliver professional development seminars for S-STEM students. The purposes of these seminars are to help S-STEM students understand professional jobs and to provide opportunities for them to connect to each other. Among the six guest speakers, three have mechanical and aerospace engineering (MAE) background, and three have civil and environmental engineering (CEE) background. Each seminar lasted approximately one hour, covering a variety of topics as follows:

Seminar #1: Application of MAE Degree
Seminar #2: Important Skills for College Students
Seminar #3: Working for Government and Industry
Seminar #4: Be Prepared and Ready to Act
Seminar #5: Working as a Mechanical Engineer
Seminar #6: Working as a Civil Engineer

For example, the speaker of seminar #4 discussed how to write and speak, how to decide what kinds of engineering work most interest students, and how to get a job. The speaker also suggested that all students take the initiative and take the Professional Engineer examination after graduation, so they can become professional engineers.

After each seminar, students were invited to respond to an anonymous online survey that included both Likert-type and open-response items. The results show that S-STEM students had positive experiences with these seminars. They reported that they would apply what they had learned from these seminars to their own college study. For example, they stated:

"I like when he talked about taking every opportunity that you can. Opportunities will come if you seek them and try to contribute."

"I learned that one of the most useful things I can do as a student is learn how to learn and continually gain more knowledge."

Student design competition

To provide an opportunity for S-STEM students to apply what they have learned from the classroom in the real world, we supported an S-STEM team for competition in the annual Pumpkin Toss community event. In this event, teams construct a medieval device (trebuchet) to launch pumpkins in a tournament of distance, accuracy, and mechanical design. Figure 3 (see next page) shows the trebuchet that the S-STEM team built.

After the event, we asked students to describe what they had learned in the aspects of technical skills (such as mechanical design and manufacturing) and professional skills (such as communication, team-working, and leadership). The following paragraphs provide two representative examples of student comments:

“During the process of designing and building the trebuchet, I learned a variety of technical skills. It was very interesting and encouraging to apply the things that I had learned in the classroom to a real engineering experience.”

“I also learned about the difference between design and manufacturability. Just because something looks good from a design perspective does not mean it can be made easily. It is important to consult someone in manufacturing to see if a design can feasibly be built. We learned this during the process of designing the trebuchet arm.”

Figure 3. The trebuchet that the S-STEM team built

S-STEM teaching seminar

To promote active learning in the engineering classroom, we organized an S-STEM Teaching Seminar for faculty members and PhD students in the College of Engineering at our university. Two members of our project team, along with three other experienced faculty members, shared with the audience our experience of using a variety of methods to promote active learning inside and outside the engineering classroom. The seminar is titled Engaging Students in Active Learning and included the following four topics:

Topic #1: How to use a classroom response system (clickers) for engaging students and assessing student learning in both undergraduate and graduate classes
Topic #2: How to use enhance guided notes (EGN) to enhance self-regulated learning in a foundational electronic course
Topic #3: How to conduct group projects in a thermal fluids lab class
Topic #4: How to conduct in-class problem solving in a large engineering classroom

After the teaching seminar, we invited attendees to provide their comments through an anonymous online survey. The survey contained both Likert-type and open-response items. The results from the survey show that attendees had a positive experience with the seminar. For example, they commented that

"All of the topics were very interesting. I have used clickers prior and am less likely to use those in the future, however I do use poll everywhere from time to time. I am interested in develop EGN for my class and in using the best practices for active learning in large classes. Problem-based learning is a potential area of research for me."

"I recently went through several of the classes of professors who presented, so I experienced the methods described. I feel the most helpful was the lecture about problem based learning and making questions more like what students will encounter outside the classroom (open ended questions). I assume this has its own special challenges though."

Concluding remarks

In this executive summary, we have described several representative project activities of our S-STEM project, including student-focused professional development seminars, student design competition, and a teacher-focused teaching seminar. The assessment results show that professional development seminars and student design competition motivate students to learn, and learn how to learn. The teaching seminar motivated instructors to think more about their own teaching and adopt active learning methods in the classroom.

Since the start of the program, four students from the program have graduated and secured jobs. One student left the program and switched to physics major due to her interest in physics. The student retention rate for this program is high. The program will continue in the next couple of years. The program progress will be reported in future papers and presentations.

Acknowledgements

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