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Impacts of Industry Seminars and a Student Design Competition in an Engineering Education Scholarship Program*

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The National Science Foundation (NSF) of the United States of America has established a Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program to provide scholarships (financial aid) and increase academic success of low-income, academically talented students with demonstrated financial need who are pursuing associate, baccalaureate, or graduate degrees in STEM. This paper describes the overall framework of the NSF-funded S-STEM program at Utah State University, including program goals and student recruitment and selection. Over the past three-year project period, 31 students were awarded S-STEM scholarships. Students could renew their scholarships for up to 4 years. A detailed description of two co-curricular activities that were particularly designed and implemented for S-STEM students is provided. These activities include S-STEM industry seminars and a student design competition. The impacts of these activities are assessed through analysis of student comments and responses to questionnaire surveys. The assessment results show that both activities have a positive impact on S-STEM students. Four lessons learned from the program implementation are described to help engineering educators adopt these activities in their respective institutions.

Keywords: Scholarships in Science, Technology, Engineering and, Mathematics (S-STEM) Program; undergraduate engineering education; S-STEM industry seminars; student design competition; assessments

1. Introduction

1.1 National Science Foundation S-STEM program

As global competition for market and technology has become increasingly intensive in recent years, business and industry have high demands for the number as well as the quality of engineers in the workforce. However, recent statistics compiled by the American Society for Engineering Education (ASEE) reveal that engineering graduation and retention rates at U.S. universities are not keeping up with the nation's increasing demands for engineering talent [1]. A recent ASEE survey found that the six-year graduation rates for engineering undergraduates varied between 38% and 67% among different ethnic student groups [2].

To meet the growing demands, efforts have been made at various levels ranging from government and professional societies to individual institutions of higher education to sponsor, develop, and implement a variety of educational programs and innovations. For instance, in 2004 the National Science Foundation of the U.S. created a Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) Program to provide financial resources and opportunities for increased academic success to low-income, academically talented students with demonstrated financial need who are pursuing associate, baccalaureate, or graduate degrees in STEM [3]. The 2004 to present S-STEM program evolved from an earlier program called the "Computer Science, Engineering, and Mathematics Scholarships (CSEMS)" program created in 1999. Recognizing that scholarships (financial aid) alone cannot automatically increase student success in STEM education, the S-STEM program encourages adaptation, implementation, and study of effective evidence-based curricular and co-curricular activities to continuously improve STEM teaching and learning [3].

1.2 Activities and impacts reported in the literature

Since the inception of S-STEM program, universities and colleges across the U.S. have received funding support from the program through a highly competitive process. The literature has reported a wide variety of student activities designed for the S-STEM program, such as cohort and leadership building [4–7], undergraduate research [8, 9], and internships [10, 11], to name a few. In working with several departments and units of their university, such as Student Services and Residential Life Offices, Kalevitch et al. [4, 5] designed and implemented Living-Learning Cohort activities for their S-STEM students. The S-STEM students lived

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in a newly renovated dormitory on campus, and two students of the same gender from the same cohort shared a room. The dormitory also had common study and meeting areas for S-STEM students. In addition to living in the same dormitory, the Living-Learning Cohort also met with industry professionals and shared their internship, co-op, and research experiences with each other.

Ferguson et al. [8] designed an S-STEM program that involved undergraduate research. Each student in their program completed two undergraduate research projects during a recent academic year. A group of faculty members served as undergraduate research mentors on a wide variety of research projects. Students conducted research and provided written reports and oral presentations of project milestones several times during each semester.

With funding support from the S-STEM program, Massi et al. [10] established a partnership between the College of Engineering & Computer Science, the College of Sciences, and the College of Business Administration at their university. Their program offered an Entrepreneurship/Internship path in which S-STEM students were placed with small incubator companies that were current or graduated clients of the university's incubator program [9]. The Entrepreneurship/Internship path helped students explore career pathways and develop professional identity.

Relevant assessment and evaluation results show that the S-STEM program has generated long-term positive impacts on participating institutions of higher education [12–14] as well as low-income, academically talented students [15, 16]. Kalevitch et al. [4, 5] reported that 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."

Improved student retention and graduation rates, among others, has often been cited as evidence to demonstrate the success of the S-STEM program [17–20]. Based on a two-sample *z*-test, D'Souza et al. [17] showed that S-STEM students in the computer science major at their institution had significantly higher retention rates than non-S-STEM students in the same major for all three academic years 2014–16. D'Souza et al. [17] concluded that through a variety of learning and mentoring activities, their program has empowered S-STEM students "(who were not necessarily stellar students) to change their academic experience and shatter through many of the socioeconomic constraints these students typically encounter."

Ricks et al. [19] also reported that the retention and graduation rates for S-STEM students at their institution were higher than most comparable cohort groups at the same institution. Based on qualitative student feedback they collected, Ricks et al. [19] concluded that "scholarships, cohort course sections, study groups, and peer mentoring/ peer relationships played a significant role in student successes."

1.3 The contributions of the present study

The program focuses on providing scholarships for undergraduate students in mechanical, aerospace, civil, and environmental engineering at Utah State University (USU). The present study adds to the existing literature by providing a detailed description of two co-curricular activities that were particularly designed and implemented for the S-STEM program at USU. The two co-curricular activities include S-STEM industry seminars and a student design competition. Although these activities have been reported in relevant literature, our assessment results of these activities provide new and deeper insights into how these activities affect student learning. Lessons learned from the program implementation at USU further help engineering educators adopt these activities in their respective institutions.

In the remaining sections of this paper, the overall framework of the S-STEM program at USU is introduced, including program goals as well as student recruitment and selection. Then, two co-curricular activities, including S-STEM industry seminars and a student design competition, are described. Assessment results are presented for each activity. Four specific lessons learned from program implementation are also described. Conclusions are made at the end of the paper.

2. Overall framework of the S-STEM program at USU

2.1 Overall framework

The S-STEM program at USU has two goals. The first goal is to provide S-STEM scholarship support for financially needy, academically talented undergraduate students in two major engineering departments in the College of Engineering, including 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 program is to train these S-STEM students to become effective scientific and technological contributors when entering the engineering workforce.

The S-STEM program at USU involves close collaboration among three departments (MAE, CEE, and the Department of Engineering Education), the College of Engineering Advising Office, the University's Financial Aid Office, and local and regional industry. The University's Financial Aid Office provides the unmet financial need information for each applicant. Four faculty members from three departments and staff members from the College of Engineering Advising Office form a Scholarship Selection Committee to review student applications and select scholarship recipients. Engineers from local and regional industry are invited to offer industry seminars for the S-STEM students.

The S-STEM program at USU consists of many components: problem-based and project-based learning activities in the engineering classroom that are open to all students including both S-STEM and non-S-STEM students, teaching seminars for faculty and graduate teaching assistants who are interested in improving their teaching skills, as well as co-curricular activities focusing particularly on S-STEM students. The scope of this paper is restricted in the description of two co-curricular activities focusing particularly on S-STEM students, including S-STEM industry seminars and a student design competition.

2.2 Student recruitment and selection

Students were recruited in three ways: email flyers, paper flyers, and classroom visits. Email flyers were sent to all undergraduate students in the MAE and CEE departments. Paper flyers were posted in all engineering buildings on campus. Visits to multiple engineering classrooms to advertise the S-STEM program were also made.

Students submitted their applications online, which included their demographic information, resumes with a list of awards or honors they had earned (if any), statements of career goals, and transcripts. The six-member Scholarship Selection Committee that consists of faculty and staff members from three departments and the College of Engineering Advising Office carefully reviewed and discussed each student application based on a comprehensive consideration of an applicant's unmet financial need and academic performance. Unmet financial need is the difference between the total cost of attendance (such as tuition, meals, and housing) and the total financial aid (such as a student's income from his/her part-time work and expected family contribution). Students' academic performance includes their cumulative grant-point-average, grades earned in important math and engineering courses, awards and honors, and so on.

Since the start of the S-STEM program at USU in 2015, S-STEM scholarships were awarded to 12 students in Year 1, 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. In other words, a total of 31 students were awarded S-STEM scholarships over the past three-year project period. Each student received \$5,000 each year for up to four years. The acceptance rate for new students applying to the program was 27% in Year 1, 13% in Year 2, and 14% in Year 3. As two examples, Figs. 1 and 2 show, respectively, the unmet financial need and the incoming graduate point average (GPA) of 26 S-STEM students in Year 2. The average unmet financial need is \$18,986, and the average incoming GPA is 3.66 for these students. The incoming GPA is the GPA when a student applied to the S-STEM program. The considerable unmet financial need and high incoming GPA demonstrate that the students we have selected are the students targeted by the NSF S-STEM program—"low-income, academically talented students with demonstrated financial need [3]." The unmet financial need and the incoming GPA were two of the criteria used when selecting S-STEM scholarship recipients.

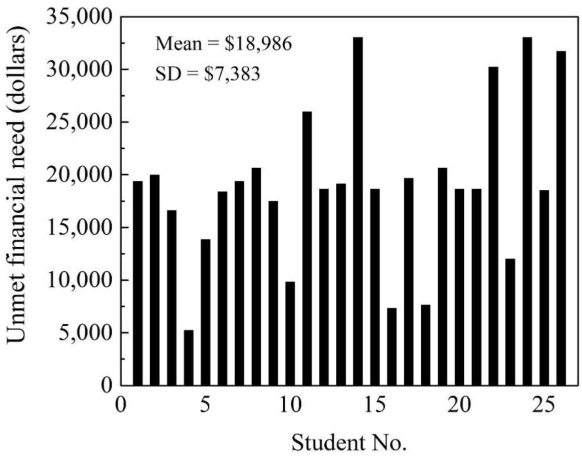

Fig. 1. Unmet financial need of 26 S-STEM students (Year 2 as an example).

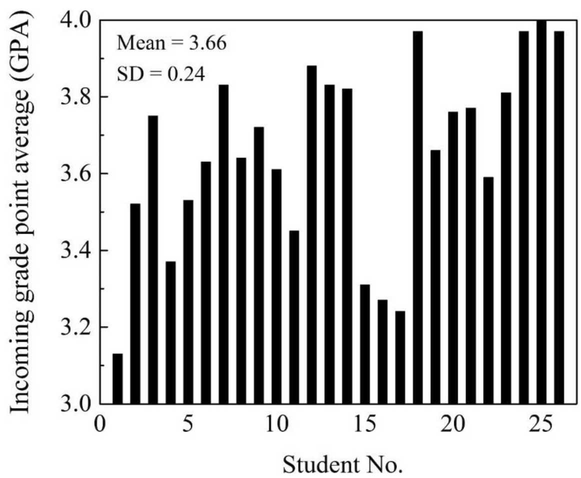

Fig. 2. Incoming grade point average (GPA) of 26 S-STEM students (Year 2 as an example).

3. S-STEM industry seminars

3.1 Seminar topics

Research evidence has shown that university-industry collaborations and interactions promote student learning in STEM education [21–25]. The engagement of industry in education shapes the direction of STEM education for higher education institutions to produce quality workforce to meet practical needs of industry.

Since the inception of the S-STEM program at USU, there have been a total of nine invited guest speakers from industry to deliver 10 professional development seminars for S-STEM students. One guest speaker delivered two seminars on different topics. The purposes of these seminars are to help S-STEM students understand professional jobs and to provide opportunities for students to connect to each other. Among the nine guest speakers, five have a mechanical and aerospace engineering (MAE) background, and four have a civil and environmental engineering (CEE) background.

The seminars were typically held in early evenings when the speakers and most students were available. Each seminar lasted approximately one hour and covered a variety of topics ranging from the projects the speakers had conducted, to how to learn, how to do job interviews, how to find internships, and how to better prepare for employment. Table 1 summarizes major topics covered in each of these S-

Table 1. Major topics covered in S-STEM industry seminars

Seminar No.	Speaker No.	Speaker's background	Major topics
1	1	BS in Mechanical Engineering (1995)	• Representative projects the speaker has conducted • Stuff from college the speaker actually uses in work • Learning multi-disciplinary knowledge in college study • Life-long learning
2	2	BS and MS in Civil Engineering (2006)	• Representative projects the speaker has conducted • Professional skills • Project-based learning • Internships • Advanced degrees
3	3	BS in Mechanical Engineering (1985)	• Representative projects the speaker has conducted • Breadth vs. depth of knowledge • Be a flexible engineer • Tips for job interviews • Advanced degrees
4	4	BS (1980) and PhD (1982) in Civil Engineering	• Representative projects the speaker has conducted • Be prepared and ready to act on every opportunity • Learn your professional interests and find your niche • Tips for job interviews
5	5	BS in Mechanical Engineering (2015)	• Representative projects the speaker has conducted • Work as a consultant • Tips for how to learn • People and communication skills
6	6*	BS in Civil Engineering (2014)	• Representative projects the speaker has conducted • Work and study balance • Advanced degrees: thesis vs. course master's • Tips for job interviews
7	7	BS in Mechanical Engineering and MS in Engineering Management (2015)	• Representative projects the speaker has conducted • Involvement with the Society of Women Engineers • Leadership skills • Work in a diverse team
8	6*	BS in Civil Engineering (2014)	• Recent virtual reality project the speaker has conducted • Communication skills • Life skills and life-long learning skills • Create your own opportunities
9	8	BS in Mechanical Engineering (2005)	• Representative projects the speaker has conducted • Internships • Student design competition • Life-long learning • Tips for job interviews and negotiation
10	9	BS in Civil Engineering (1995)	• Representative projects the speaker has conducted • Experiences of leading a Design and Consulting Services group • Government vs. private jobs • Tips for college study • Tips for working as a professional

* The same speaker No. 6 delivered seminars Nos. 6 and 8 on two different topics.

STEM industry seminars as well as the speakers' backgrounds.

As can be seen from Table 1, the speakers have diverse experiences and backgrounds in engineering and include senior engineers who earned their BS degrees in 1980, 1985, and 1995 as well as junior engineers who earned their BS degrees in 2014 and 2015. S-STEM students were hence benefited from different perspectives offered by these diverse speakers. As two examples, the following sections describe seminars Nos. 1 and 8. The two seminars focus on the work in the fields of mechanical and civil engineering, respectively.

3.2 Example 1: seminar No. 1

The speaker of Seminar No. 1 is a senior mechanical engineer (BS in 1995) and has been working in the mechanical engineering field for more than 20 years. He described several representative projects he had conducted as well as the products of his current company, such as servo controller products and robotic arm products. He then listed nine engineering courses/topics that he had learned during his undergraduate study and that he actually used quite often in his professional work after graduation. The nine engineering courses/topics he listed include statics, dynamics, machine design, solid modeling, programming, fluids, heat transfer, materials, and controls. He emphasized that mechanical engineering students also need to learn knowledge from other disciplines, such as electrical and computer engineering. He told students that all the projects he had conducted involved programming and controllers, which are highly related to electrical and computer engineering.

The speaker also emphasized that life-long learning is important because the completion of a real-world project often requires multi-disciplinary skills. He shared with students his own experiences on how to learn knowledge of a new discipline. For instance, he said that an engineer should learn important vocabularies in the new discipline first, so the engineer can ask the correct questions to the professionals in that discipline.

At the end of the seminar, students asked many questions. For example, one student asked "For new graduates with no work experience, how to deal with a new project?" The speaker replied that confidence is more important than abilities when doing a new project at the beginning stage. The speaker created a new term called analysis 2: analyze what needs to be analyzed and then analyze it. He said that after product design, one cannot analyze every aspect of the product due to the short lead time to bring the product to market. Therefore, one must focus on the most important aspects of the product, i.e., analyze what needs to be analyzed.

3.3 Example 2: seminar No. 8

The speaker of Seminar No. 8 is a junior civil engineer (BS in 2014) and has been working for nearly four years after graduation in an international consulting firm that focuses on civil engineering. During the seminar, the speaker demonstrated to students a 3D virtual reality project that he had recently conducted. The 3D virtual reality software he created allows users to observe water supply in a multi-story building with a complex water supply system. Students were invited to try out the headset to experience the excitement of what 3D virtual reality could aid in the design process.

Based on his own work experience, the speaker emphasized the importance of communication skills. He said that as an engineering consultant, he has written numerous technical reports and worked with many clients to solve their problems on a daily basis. He encouraged students to develop life skills and life-long learning skills by getting involved with the American Society of Civil Engineers (ASCE), undergraduate research, and ASCE National Concrete Canoe Competition, a team competition attracting numerous civil engineering students across the nation and challenging students' knowledge, creativity, as well as team working and project management skills.

At the end of the seminar, students also asked many questions. For example, students asked "how did you get into this position?" and "what set you apart in your job interview?." Four career path options were also discussed, including 1) engineering BS and MBA, 2) engineering BS and engineering MS, 3) engineering BS with business minor, and 4) engineering BS with internships in a business firm. The speaker encouraged students to earn a Master's degree because the consulting firm he has been working for hires more and more graduates with MS degrees.

3.4 Assessment results

After each seminar, students were invited to respond to an online anonymous questionnaire survey that included the following Likert-type and open-response items:

1. What is your overall learning experience with this S-STEM industry seminar?
   (a) Highly positive
   (b) Positive
   (c) Neutral
   (d) Negative
   (e) Highly negative
2. Describe specific things that you have learned from the speaker's talk and that are useful to you.
3. Describe how you will apply what you have

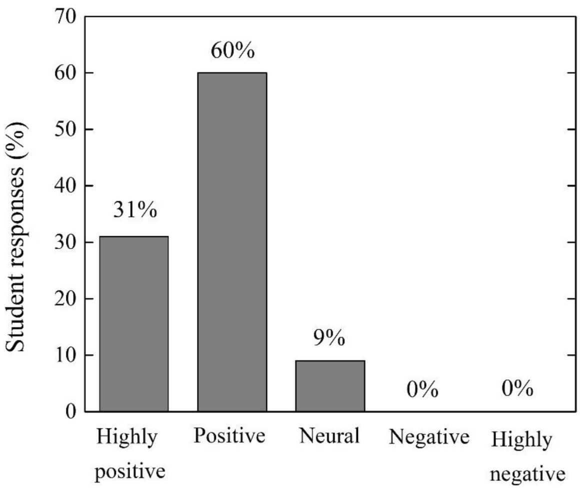

Fig. 3. Student rating for S-STEM industry seminars.

learned to your undergraduate or concurrent B.S./M.S. study.

A total of 55 student responses were received from ten questionnaire surveys, with one survey for one seminar. Fig. 3 shows student responses for survey item No. 1. As seen from Fig. 3, students rated their overall learning experiences with the seminars highly positive (31%), positive (60%), and neutral (9%). No students rated their experiences negative or highly negative. These results show that students had positive experiences with industry seminars.

A qualitative research method known as content analysis [26] was employed to analyze student written responses to survey items Nos. 2 and 3. The content analysis involved coding, i.e., categorizing, the collected data, member checks, and then counting the frequency of a particular code. The coding process was iterative and involved both open coding and axial coding [27]. In open coding, the data was studied several times to create initial tentative codes that covered common themes. In axial coding, core themes were disaggregated [27].

Tables 2 and 3 summarize the codes emerged from content analysis, the frequency of each code, and representative student responses for each code for survey items Nos. 2 and 3, respectively. Note that one or multiple codes were generated from the content analysis of responses from the same student. Therefore, the number of codes shown in Tables 2 and 3 is not necessarily equal to the number of students. The higher the frequency of a particular code, the more students provided the same or similar responses.

The nine codes included in Table 2 represent student responses to survey item No. 2: specific things that students have learned from the seminars.

Table 2. Results of content analysis of student responses to survey item No. 2

Code	Frequency	Representative student responses
Learn as much as possible	3	• There is hope in the future and it is important to learn as much as we can in our studies. • Continue to always learn even after graduation.
Learn how to learn	3	• 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. • It was reemphasized to me the importance of learning how to learn.
Learn important subjects in my major	2	• What subjects to play close attention to because of their highly probable use after class. • What things that he feels are useful to him that he took from school.
Find out what interests me most.	4	• I learned that it is important to go after what you think is interesting. You can accomplish a lot more and life is more interesting if this is done. • Experience many jobs so you can know what you dislike.
Look for and take any opportunity	5	• I like when he talked about taking every opportunity that you can. Opportunities will come if you seek them and try to contribute. • Take opportunities that are presented and present myself well to others.
Professional skills needed in industry	5	• How important people/communication skills are when finding a job, and working. Getting more involved in groups and leadership. • He mentioned the need to be a problem solver, or one who is willing to figure things out. This is important for becoming a good leader and engineer.
Job opportunities	14	• I learned that there are positions and jobs for mechanical engineers for design and that I don't necessarily have to specialize in something else to be hired as a Mechanical Engineer. • His advice and his choices for the path to take for water engineering was very valuable to me. I really liked the knowledge about consulting. It good to know the options out there for us as we enter the field.
Jobs requiring a Master's degree	7	• I learned that many companies want students with a master's degree in the mechanical engineering industry. • He changed my perspective of graduate school and when I should go. I am more interested in the concurrent program now as well as looking into other possibilities in the near future.
Tips for preparing and getting jobs	9	• His advice to actually contact somebody in the company by phone instead of just submitting a resume online. • His advice about spending adequate time in interviews for jobs is really helpful.

Table 3. Results of content analysis of student responses to survey item No. 3

Code	Frequency	Representative student responses
Learn as much as possible	5	• I am going to learn as much about everything that I can even if it doesn't deal specifically with my major. • I will continue to seek to take more variety of classes (especially electrical engineering classes) in addition to my regular MAE classes.
Learn how to learn	3	• I am going to try to do more to find ways to learn. There are a lot of sources of knowledge, and I need to seek out those sources. • Ponder on my learning methods and how I can improve them.
Learn important subjects in my major	5	• I'm going to start focusing on computer programming so that I can build fun things but know how to program them, too. This was also a good opportunity for me to relax and pick my chin up during a rough week of tests and homework. • I am rethinking my decision to not take Controls or Mechatronics.
Improve professional skills	3	• I want to be more involved in groups and leadership roles while in college and building stronger relationships with my professors. • Make plans for how to balance time between my wife and my jobs, and our time together with each other and our son.
Open mind and expand knowledge base	5	• I will open my mind to other things that I can work on and the other problems that I can solve with my degree. • I will not be narrow minded and further realize my potential and consider broader career opportunities.
Be proactive	12	• I feel like after last night I will be much more proactive as a student seeking out internships, research, and other scholarship opportunities. • I am currently involved in undergraduate research, and I plan to become more involved in clubs and extracurricular activities.
Explore a Master's degree option	11	• I plan on getting involved in undergraduate research, and obtaining a MS in Civil Engineering. • I will definitely continue looking for options for graduate school.

The meanings of these codes are self-explanatory. Students learned that they should:

- Learn as much as possible
- Learn how to learn
- Learn important subjects in my [student's] major
- Find out what interests me [student] most
- Look for and take any opportunity

Students also learned:

- Professional skills needed in industry [such as communication skills, leadership skills, time management, and setting priority]
- Job opportunities [as a mechanical/aerospace or civil/environmental engineer]
- Jobs requiring a Master's degree
- Tips for preparing and getting jobs

From Table 2, in terms of the frequency of a code, all of the top three concepts students have learned from the seminars are job related: job opportunities as a mechanical/aerospace or civil/environmental engineer (frequency: 14), tips for preparing and getting jobs (frequency: 9), and jobs requiring a Master's degree (frequency: 7).

The seven codes included in Table 3 represent student responses to survey item No. 3: how students will apply what they have learned to their undergraduate or concurrent BS/MS study. Four codes in Table 3 are the same as those included in Table 2. The meanings of the seven codes in Table 3 are also self-explanatory. Students stated that they would:

- Learn as much as possible [with various learning approaches listed in student responses]
- Learn how to learn
- Learn important subjects in my [student's] major [with specific subjects listed in student responses]
- Improve professional skills [such as communication skills, leadership skills, time management, and setting priority]
- Open mind and expand knowledge base
- Be proactive [such as do internships and undergraduate research]
- Explore a Master's degree option

In terms of frequency, two codes stand out from Table 3. Students indicated that they would be proactive through internships and undergraduate research (frequency: 12) and also explore a Master's degree option (frequency: 11). None of the other five codes has a frequency more than 5. These results show that S-STEM industry seminars have generated a positive impact on students in terms of encouraging students to be proactive and explore the option for graduate study.

4. Student design competition

4.1 Design project

Research evidence has shown that one of the most effective approaches to improving student learning outcomes is to actively involve students in engineering design [28–32]. In the S-STEM program at USU, opportunities have been provided for S-STEM students to apply what they have learned in the classroom to engineering design in the real world. The program has supported an S-STEM student team for competition in the annual state-wide event called Pumpkin Toss. In this event, student teams from universities and colleges across the State of Utah construct a medieval device called a trebuchet to launch pumpkins in a tournament of distance, accuracy, and mechanical design. The event is an excellent showcase of how engineering and science principles can be applied in the real world.

The S-STEM students who were interested in attending the Pumpkin Toss competition formed a six-member S-STEM team. Each member has a different role and responsibility on the team. Over a five-week project period, the team met on a regular basis to discuss project tasks and solve various issues involved, including base and frame design, trebuchet arm design, counterweight box design, as well as the manufacture, assembly, and field testing of the trebuchet.

For example, in the initial base and frame design, the team met to discuss competition criteria and design specifications. The base of the trebuchet must fit within a 10 by 10 square feet footprint. The fulcrum height could not exceed 15 feet. The maximum counterweight was 300 lbs. Multiple safety measures were also required to prevent misfires. Students used Solid Works to create designs and bought necessary materials, such as wood, nuts, bolts, and steel pipes, to build the trebuchet. Fig. 4 shows the final trebuchet designed and built by the S-STEM student team. The trebuchet shown in Fig. 4 consists of a wood base, a wood frame, a steel arm, and a counterweight box. The base and the frame support the arm, which is used to launch pumpkins.

Fig. 4. The trebuchet designed and built by the S-STEM student team.

4.2 Assessment results

After the Pumpkin Toss event, students were asked to describe what they had learned from their experiences in the aspects of technical skills, such as mechanical design and manufacturing, and professional skills, such as communication, team-working, and leadership. The participating S-STEM students provided positive comments in both aspects. In the aspect of technical skills, representative student comments are:

> "I 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."

> "I learned a lot in this process about design to accommodate a series of parts from different places as well as designing parts that accomplish the task in an efficient manner. When I refer to accommodating parts I learned a big lesson in tolerances. We designed the center of the junction piece to accept a flange bearing on either side so that the main support axle would pass through the bearings and connect to the main base support arms. The bearings were given as a 2 inch inside diameter and our axle was a 2 inch outside diameter. On paper they should have fit together perfectly, but it turned out that the axle and the bearings did not meet up due to conflicting tolerances. Another instance was designed, for example, a 3/8th inch hole to accept a 3/8th inch bolt. We ended up being able to make it work, but this lesson in tolerances will be a big one for me."

In the aspect of professional skills, representative student comments are:

> "Building this trebuchet gave me a deeper understanding of how to effectively communicate with a team and problem solve alongside team members. I also learned important leadership skills and how to remain calm under pressure."

> "At different times throughout the designing and building process, several of us acted as team leader. When one person's background and experience made them the authority on that portion of the trebuchet, they acted as leader, and we each referred to them with questions and possible solutions to issues. During my time as a leader, I learned the importance of expanding my own opinions and being open to the solutions of my teammates. I learned to trust the opinions of others and value all the ideas that came forward."

> "I learned a great lesson from my fellow team members in dealing with difficulties and not getting frustrated when things go wrong. We ran into a few bumps, but were able to press on and make it work. There will always be difficulties, but it was great to be part of a team that had members that were able to help the others work through problems to ultimately be successful. We ran into some problems with getting all of the team members to contribute the project being volunteer based, but luckily enough people ended up contributing and were able to have a great experience. I also gained some good experience in project timing and working with the suppliers that we used. Just as in the experience of the build, something will always go wrong but if there is time built into the project timeline for it things go much more smoothly and enjoyably."

One S-STEM student made the following conclusion:

> "In addition to gaining greater knowledge and understanding of the technical and professional world, building the trebuchet and participating in the Pumpkin Toss competition was a lot of fun. I feel like I was able to put my coursework to the test and see a design come to life. It was rewarding to see the hard work of our team pay off and be able to successfully launch pumpkins several hundred feet. I believe the lessons of teamwork, leadership, and problem solving that I learned are highly valuable."

5. Lessons learned

Four important lessons were learned during the implementation of the S-STEM program at USU. First, classroom visits are more effective than email and paper flyers to recruit students to participate in the S-STEM program. For example, in the second year of the program, the program was initially advertised via email and papers flyers. Over a forty-day period, only sixty-seven applications were received. The project team then visited several engineering classrooms to advertise the program and provided students an opportunity to interact with the project team and get their questions answered immediately. As a result, as many as twenty-four more applications were received just within three days after the classroom visits.

Second, it is important to determine the dates of S-STEM industry seminars as soon as possible, so students can make the dates and times available from their busy schedule. The vast majority of the S-STEM students work part time outside the campus in addition to their regular college study. The project team has made significant efforts to coordinate with the industrial speakers and let students know the date and time of a seminar as least one week, most often 10 days, in advance. The time of seminars is typically in early evening around dinner time. Free pizzas are provided to all students so as to encourage them to attend.

Third, timely assessments should be incorporated into all program activities in order to receive student feedback and make continuous improvement of the program. Within 24 hours after each industry seminar, students were invited to submit their anonymous written comments to an online website. The analysis of student comments helped understand the impacts of these seminars.

Fourth, it is important to provide just-in-time support for the S-STEM student team to conduct and complete their design project. The project team was accessible and available when students had technical or budgetary questions for discussions. The project team even went with the students to manufacturing facilities to make some parts students designed for building the trebuchet. Faculty-student interactions are critical to ensure students had an enjoyable and rewarding experience on their design project.

6. Conclusions

This paper has described the overall framework of the S-STEM program at USU, including program goals as well as student recruitment and selection. The paper has also described the details of implementation and assessments of two co-curricular activities that were particularly designed for the S-STEM students. The following two paragraphs summarize major findings reported in this paper.

S-STEM industry seminars helped S-STEM students understand professional jobs and provide opportunities for students to interact with each other. Students rated their overall experiences with these seminars highly positive (31%), positive (60%), and neutral (9%). No students rated their experiences negative or highly negative. The results of content analysis of student responses to open-ended survey items show that all of the top three things students have learned from the seminars are job related: job opportunities as a mechanical/aerospace or civil/environmental engineer, tips for preparing and getting jobs, and jobs requiring a Master's degree. Students indicated that they would be proactive through internships and undergraduate research and they would also explore a Master's degree option.

Student design competition via the Pumpkin Toss event provided an excellent opportunity for S-STEM students to apply what they had learned in the classroom to engineering design in the real world. Student comments about their experiences demonstrate that they have benefited not only from the improvement of technical skills, such as mechanical design and manufacturing, but also from the improvement of professional skills, such as communication, team-working, and leadership.

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