Promoting STEM through Hands-on Sessions and Field Trips (Evaluation, Diversity)

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Abstract

This paper describes a summer enrichment program focused on improving student preparedness for college, while promoting STEM education through active learning experiences and activities. The program is a partnership with industry and designed to introduce participants to various engineering disciplines through two field trips and hands-on activities that include sessions in chemistry, biology, physics, mathematics, computer science, electrical engineering, civil engineering, and mechanical engineering. These activities provide participants with important knowledge and skills to gain a better understanding of science and engineering careers. A major benefit of the program is ensuring a strong pipeline of STEM talent while paying special attention to the mentoring, training, and recruitment of the underrepresented population in STEM, especially women and minorities. This paper presents program details and recent evaluation results.

Introduction

The number of science, technology, engineering, and mathematics (STEM) jobs in the United States is growing faster than ever. According to the Bureau of Labor statistics, while total employment is projected to increase by 2.8% from 2022 to 2032, STEM jobs are expected to grow 10.8% during the same period [1]. This translates into more than one million new STEM jobs in the American labor market over the next 10 years. This demand for STEM graduates is of interest to many colleges and universities, where the focus has been on increasing efforts that support the recruitment and success of students in STEM [2-9]. Furthermore, many universities have implemented a variety of programs that employ high impact retention approaches, including advising, mentoring, active learning, student engagement, and other support services. [10-14]. While there are many causes that result in low graduation rates, it is more likely that rates could be improved if students are well-prepared for college and have clear future career goals. Studies have shown, for example, that K-12 students who participate in STEM programs increase their chances to succeed in STEM disciplines once they are in college. Such programs provide participants with important knowledge and skills and help them gain a better understanding of science and engineering careers. This is especially important to underrepresented populations in STEM as active learning opportunities have been shown to increase interest and improve retention.

This paper describes a two-week summer enrichment program that improves student preparedness for college, while promoting STEM education through active learning experiences and hands-on activities. The program was initially developed in 2016 with a focus on introducing participants to various engineering disciplines through hands-on activities and participation in two field trips to facilities that employ engineers and scientists. Rising high school juniors and seniors are recruited via a program web site or through guidance counselors, STEM teachers, and principals. Social media is also used as a recruitment tool. Applicants are evaluated using selection criteria that include high school transcripts, demographics, and an essay where students describe their reasons for wanting to attend. Program staff included 10 faculty members, two lab

managers, and three student assistants (two undergraduates and one graduate student). In summer 2023, 28 students successfully completed the workshop. The group included 17 female students and 15 out of the total were minority (none-white, self-reported) students. Participants came from 14 regional high schools. This paper presents the 2023 program data and results, in addition to sharing recruitment outcomes from the 2016, 2017, and 2018 cohorts.

Student Recruitment

Recruitment for the STEM-SEP program begins in January of each year. The program has a designated webpage located on the School of Science, Engineering and Technology's website (https://harrisburg.psu.edu/science-engineering-technology/STEM/summer-STEM-program). The webpage includes an overview of the program, activities, application, as well as specific pages targeted towards parents and students. A flyer is sent electronically to high school guidance counselors, principals and STEM educators. The Office of Marketing and Communications at Penn State Harrisburg assists by distributing the program information via social media and relevant news outlets. The program has grown in popularity in the region and word-of-mouth has become an effective means of recruiting students.

Workshop Sessions

As mentioned in the introduction, the pedagogical techniques employed in all of the workshops are active-learning student-centered methods. Session contents are determined by the instructors based on what they determine is most effective to introduce their topics and disciplines. Sessions normally include lecture presentations followed by activities that teach the concepts through demonstration or experiment that the students perform themselves. The session descriptions below are reflections of the 2023 workshop. A particularly important component of the program that makes this possible is the inclusion of teaching assistants that are current undergraduate students. These teaching assistants, close in age to the participants and trained right before the workshop begins, make it possible to hold large lab-based classes.

The workshop starts with registration and a welcome session where parents and students meet the faculty and staff. A field trip is normally scheduled during the first week and another one during the second week. One of the field trips is a tour of a local steel manufacturing facility that takes steel from raw material to finished rail products. The second tour is normally to a local hospital where the emphasis is on educational and training facilities. The workshop concludes with brief student presentations, the award of certificates, and a reception. In their presentation, students typically comment on their favorite learning experience during the workshop and how what they learned would impact their future career plans. Table 1 shows the 2023 workshop schedule and the following paragraphs provide brief descriptions of workshop sessions.

Mathematics: During this session, students learned about coding theory, history and technology. Students were taught integers modulo and cut out two wheels to make their own ciphers. A cipher is an algorithm for encrypting or decrypting messages. During this time, students encrypted their own messages and let other students decrypt them. Students also learned about cryptology through other ciphers like the affine ciphers and other ways of encryption and decryption like error correcting code and public key encryption. In addition, vectors and matrices

were also introduced as a way to encode information strings. Students also explored code design and its intersection with geometry in the code space.

Table 1. 2023 STEM Summer Enrichment Program

		9-12 noon	12-1	1-4 PM
Week 1	M 6/12	Registration and opening ceremony with parents & faculty. Tour of campus facilities.	Lunch	Math Applications – Coding Theory and Cryptology
	T 6/13	Civil Engineering: Building Materials	Lunch	Civil Engineering: Bridge Design
	W 6/14	Field trip 1: Cleveland-Cliffs Steelton Plant	Lunch	Chemistry: Qualitative Analysis
	Th 6/15	Mechanical Engineering: Aerodynamics	Lunch	Mechanical Engineering: CAD & 3D Printing
	F 6/16	Biology: DNA Characteristics	Lunch	Biology: DNA Profiling
Week 2	M 6/19	Juneteenth Holiday: No Program		
	T 6/18	Computer Science: Programming & Algorithms	Lunch	Computer Science: Algorithms in Bioinformatics
	W 6/19	Physics: Optics	Lunch	Field trip 2: Penn State Health Simulation Labs
	Th 6/20	Electrical Engineering: Robot Construction	Lunch	Electrical Engineering: Electronic Circuits
	F 6/21	Work on project/presentation	Lunch	Closing Ceremony: Presentations, awards, social

Civil Engineering: This session included an overview of past, present and a glimpse into the future of structures. In addition, students learned about material behaviors and their different properties such as stress, compression, tension, strength and toughness. Then, students performed several stress tests on samples of steel. Students also learned about the properties of concrete and tested different samples under stress. Later, they manufactured their own boats out of concrete. Lastly, students learned about different types of bridges and created their own out of popsicle sticks and hot glue in groups of 3 to 4. At the end of the session, students tested the strength of their bridges by hanging weights off the bottom of the bridge.

Chemistry: During the Chemistry session the students were told there was an outbreak of the zombie flu and they had to determine who was infected and what was the antidote. To do this, students used density, gas chromatography, paper chromatography, and an ELISA test. Chromatography is the separation of a mixture through suspension. Paper chromatography was used to separate the colors in a pen during this session while gas chromatography was used to separate a liquid into its different parts. These two types of chromatography were used to determine the antidote. Then, an ELISA test, which detects certain antibodies, was used to determine who was infected.

Mechanical Engineering: Students learned about plastic products and different types of materials, including their respective features, used in manufacturing. Students formed groups and were given 10 minutes to search for plastic products around the building and discuss the manufacturing process of the objects found. After learning about traditional plastic molding, students were introduced to 3-D printing and were challenged to compare both methods of manufacturing. They also analyzed the implications of such differences, such as cost, design complexity implications, material diversity and composition. Lastly, students used 3-D printing pens to design and build a small bridge. The bridges were tested for stability and prizes were

awarded for the best designs. Later, students learned about 3-D scanning and some of its applications, such as producing human models for films, as well as the inner workings of a 3-D scanner.

Biology: Students broke up into two groups to focus on DNA and cell characteristics. In the first group, students were tasked with developing a bioreactor to keep hypothetical alien cells alive. The conditions analyzed were the tonicity of the media, where students learned about osmosis, diffusion, and hyper/hypo/isotonic solutions. They worked with osmosis dialysis tubing to determine in which samples of differing molarities the cells were isotonic. Secondly, students tested and determined pH levels where amylase worked and denatured, finding the optimal conditions to maintain the alien cells. In the second group, students learned about antigens and antibodies followed by simulated blood testing and typing. They then determined which sample tested could be used as a donor for a patient. The session concluded with a lesson on resting and active heartbeat.

Computer Science: Students were taught about basic functions and elements in Java such as variables and mathematical operations. They had access to a programming website where they were able to test their codes. Students learned about loops, Boolean operators, and if-else statements. Throughout the lesson students were quizzed on what they learned and given prizes. In the afternoon period, students learned about arrays and later implemented them in methods. Students developed a multiplication function utilizing recursive recall. With the recursive recall knowledge, students wrote a program to print the numbers in the Fibonacci Series. Lastly, they attempted to implement dynamic programming into their Fibonacci algorithm codes.

Physics: Students were introduced to the topic of physics and how it intersects and is the basis for many other fields. Students learned about optics and some of its history. Then, they analyzed the shadow of a laser on a projector to identify the properties of light. The first activity involved dropping clear nail polish over water to produce circular rainbow patterns and observe the properties of light refraction. The patterns formed on a black cardboard surface that, after dried, the students were allowed to take home. Next, they worked with laser pointers to study the different behaviors of light, how it can change and how to calculate frequency of a light source based on observable distance. With the laser pointers, the professor used a real-world example of how laser pointers are used. Lastly, the students were given light refractor glasses and observed the light emission patterns of several elements, such as helium gas, hydrogen gas, mercury and a plasma ball.

Electrical Engineering: Students were introduced to basic electrical vocabulary and photonics, as well as basic soldering techniques. They learned about various components, including resistors, transistors, capacitors, batteries, and circuit boards. With the soldering knowledge, they created a small photo sensing robot by soldering all the parts to a given board. The resulting robot was controlled by light. In the afternoon, students were introduced to a sonogram and a synthesizer, and taught how they relate to musical instruments such as the keyboard. They were also able to play the keyboard and make music with the synthesizer. In succession, a frequency hearing test was performed to measure how high and low of a frequency students could detect with their ears. Through these activities students were able to visualize the waves emitted through the sonogram. They also measured flicker fusion frequency, the frequency at which a flickering light looks like a still image.

Field Trip 1 - Cleveland Cliffs Plant in Steelton: During this field trip, students learned about the history of the plant, the oldest steel factory in the U.S. An overview of the steel and rail making process was given. By continuous casting, the steel is shaped into blooms which are then processed into a variety of lengths. Through said processing, the blooms result in different final products, including rails, to be sold to the market. A small fraction of blooms is sold unprocessed. Similarly, safety processes and requirements were explained. After the presentation, students got a tour of the plant and were given demonstrations of quality testing done at the facility, as well as the machinery used in the process of steel and rail making itself.

Field Trip 2 - Hershey Medical Center Simulation Laboratory: During this field trip, students were able to see and try common protocols for CPR, IV injections, intubation and respiratory rescue on complex mannequins. In the respiratory section, students were shown how professionals in training use the mannequins and equipment to practice procedures for critical medical situations. Students got the chance to intubate the mannequin and to visualize how a respiratory assistance machine works on the body using a pig's lung. In the CPR section, students practiced CPR on a mannequin. In addition, students had the opportunity to operate a da Vinci surgical system through a game exercise. Lastly, students played a scavenger hunt on a mannequin looking to identify several medical equipment placed on the patient. They also learned about medication administration and IV injections.

In addition to the activities described above, staff from our Office of Multicultural Recruitment and Community Affairs presented to students on the college application process. The purpose of the session was to aid students in preparing for college and answer any questions they have about the process.

Evaluation of Sessions

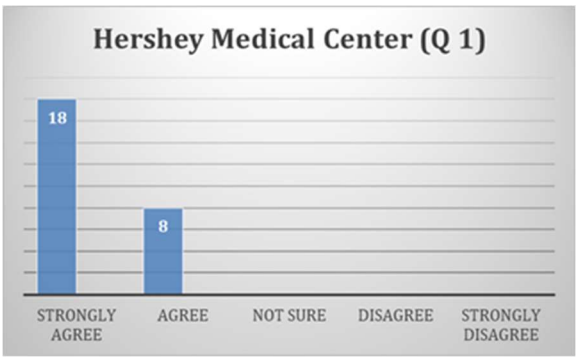
Workshop sessions were evaluated by participants using the form shown in Appendix A. A score of 100% would indicate that all the students had answered "Strongly Agreed" or "Agreed." The results from the five questions asked at the end of each session are presented in Table 2. As can be seen, almost all sessions were well received by the students. In particular, student responses indicate that sessions contributed to their learning and understanding of STEM. The last column indicates that the sessions also increased their interest in STEM, with mechanical engineering, biology, civil engineering, and chemistry being highly rated.

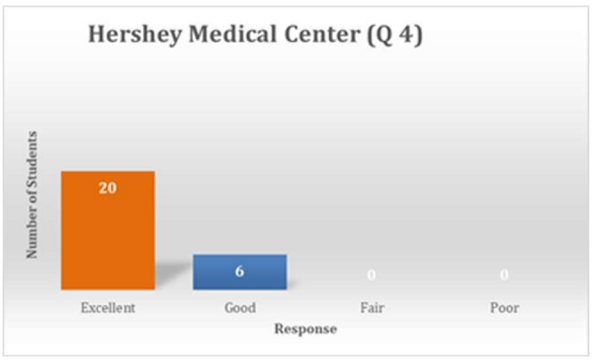
Table 2. 2023 Evaluation results from Appendix A for individual sessions

Session	Understanding	Learning	Fun	Material Usability	STEM Interest
Mathematics	71%	68%	40%	96%	46%
Physics	86%	89%	89%	85%	81%
Civil Engineering	96%	93%	96%	94%	86%
Chemistry	96%	89%	93%	100%	86%
Mechanical Engineering	96%	96%	100%	100%	100%
Biology	100%	96%	100%	92%	88%
Computer Science	70%	56%	48%	59%	56%
Physics	89%	89%	89%	85%	82%
Electrical Engineering	89%	89%	89%	85%	82%

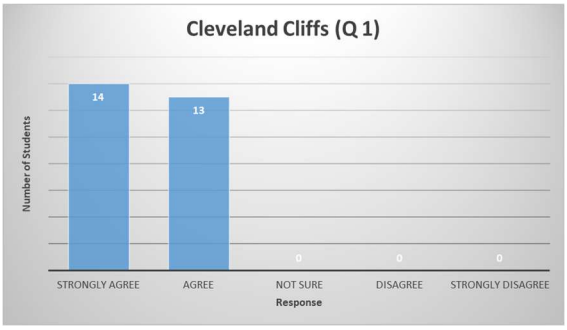
Evaluation of Field Trips

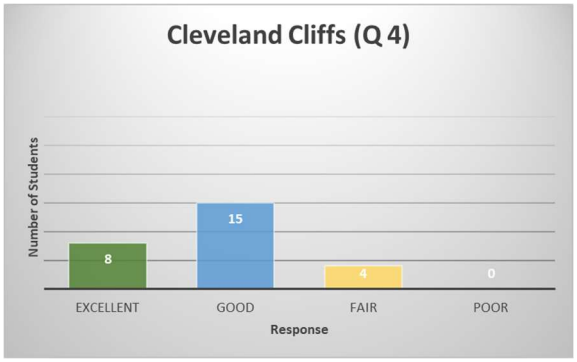
The field trips were evaluated by participants using the form shown in Appendix B. The feedback for questions 1 and 4 is plotted in Figure 1.





(a)





(b)

Figure 1. Evaluation of Field Trips

Overall Workshop Evaluation

Students provided feedback on the last day of the workshop using the form shown in Appendix C. The results are shown in Fig. 2 below.

While the results of Figure 2 agree with the earlier feedback shown in Table 2, the electrical engineering session was rated highest when compared with all other sessions and the field trips are among the highly rated activities.

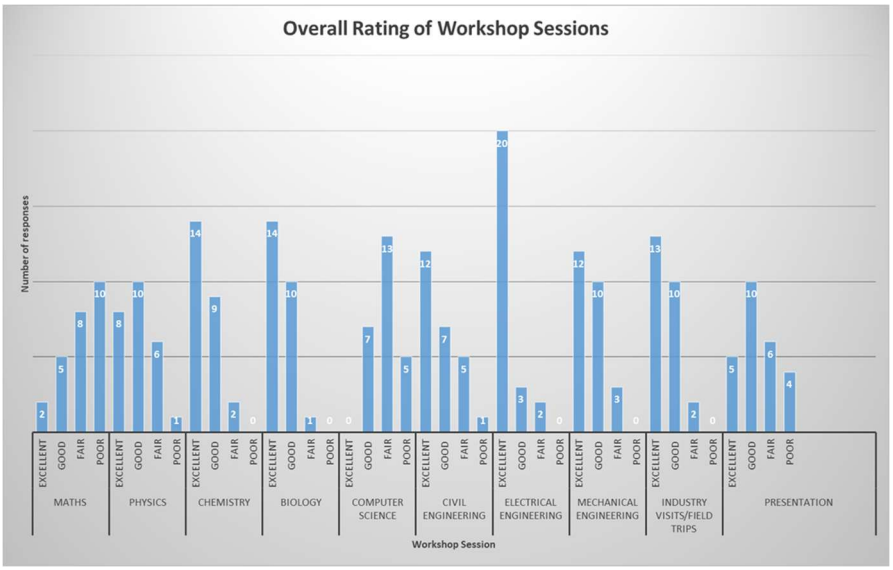


Figure 2. End of Workshop Evaluation of all Sessions

Follow Up Analysis

To help us examine the success of STEM-SEP in recruiting students to Penn State, we took a close look at the 2017-2019 cohorts. The results are summarized in the following table. As can be seen, the number of workshop participants over three years who enrolled in a STEM major at Penn State ranges from 34% to 40%. This is considered a positive outcome since many other students may have selected other STEM majors elsewhere.

STEM-SEP YEAR	2019	2018	2017
Total # participants	**32**	**62**	**32**
# of students enrolled at PSU	**13**	**21**	**11**
% of enrolled of total	**40%**	**33.8%**	**34%**

Conclusion

The 2023 STEM-SEP was successful in achieving its major objectives. Feedback from students shows that the workshop activities were fun and effective in exposing participants to STEM disciplines and career opportunities. As a testimonial to the success of the program, most students mentioned Cleveland Cliffs in their final presentation and thanked the company for sponsoring the workshop. Moreover, several parents spoke with program faculty and staff during the ice cream social on the final day of the workshop and thanked them for a well-organized and successful program. Data from the 2017, 2018, and 2019 cohorts show that close

to 36% of all participants selected Penn State for their college studies. This feedback is important as it supports our plan to expand the program to attract more students to our STEM programs.

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Appendix A

STEM-Summer Enrichment Program (STEM-SEP)
June 12, 2017-June 23, 2023

Session Feedback Form

Session:_____

Date and Time:_____

Please complete the following questions:

1. This session added to my understanding of STEM
   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

2. I learned a lot from this session
   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

3. This session was fun
   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

4. Supplies and training materials were easy to use
   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

5. As a result of this session, I am more interested in STEM
   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

Please use the following space to write any additional information you would like to share with us regarding this session:

Appendix B

STEM-Summer Enrichment Program (STEM-SEP)
June 12, 2017-June 23, 2023

FIELD TRIP FEEDBACK FORM

Field Trip to:_____

Date: _____

1. This field trip increased my understanding of the operation of laboratory/industrial facilities?

   __Strongly agree __Agree __Not sure __Disagree __Strongly disagree

2. The most important thing I learned from participating in this field trip was:

3. This field trip can be improved if:

4. Overall, this field trip was:

   ___Excellent ___Good ___Fair ___Poor

5. Other comments. _____

Appendix C

STEM-Summer Enrichment Program (STEM-SEP)
June 12, 2017-June 23, 2023

Workshop Feedback Form

Please complete the following questions.

	Excellent	Good	Fair	Poor
6. Rating of individual workshop sessions:				
a) Math Activities	❒	❒	❒	❒
b) Physics Activities	❒	❒	❒	❒
c) Chemistry Activities	❒	❒	❒	❒
d) Biology Day (Biofuels Lab)	❒	❒	❒	❒
e) Computer Science Day	❒	❒	❒	❒
a) Civil Engineering Day	❒	❒	❒	❒
b) Electrical Engineering Day	❒	❒	❒	❒
c) Mechanical Engineering Day	❒	❒	❒	❒
d) Industry Visits/Field Trips	❒	❒	❒	❒
e) Preparing for College Session	❒	❒	❒	❒
f) Project presentations and awards (final session)	❒	❒	❒	❒
7. My overall rating of all workshop sessions is	❒	❒	❒	❒