A Summer Enrichment Program to Prepare Students for STEM Majors in College

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Abstract
The shortage of STEM graduates in the United States has been the focus of numerous recent reports. Data compiled by the American College Testing in 2008 shows that the overall four-year engineering graduation rate was 22% in public schools and 45% in private schools. 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. This paper presents the results of a new two-week summer enrichment program that focuses on improving student preparedness for college, while promoting active learning through hands-on experiences and activities. Students were introduced to various engineering disciplines through hands-on activities that included topics in chemistry, biology, physics, mathematics, computer science, electrical engineering, civil engineering, and mechanical engineering. The program also included two field trips where students toured a science laboratory and a manufacturing plant that employ scientists and engineers from different disciplines.

Introduction
In 2014, nearly 45% of incoming freshman undergraduates entered college planning to major in science and engineering fields according to the 2016 NSF's National Science Board Report on Science and Engineering Indictors[1]. This incoming large flux of students is essential to reduce the shortage of STEM graduates in the United States[2-4]. Studies have shown that students who participate in STEM programs before college increase their chances to succeed[5-8]. These programs provide them with important knowledge and skills and help them gain a better understanding of science and engineering careers.

This paper describes a two-week STEM Summer Enrichment Program (STEM-SEP) designed for high school students. STEM-SEP's goal is to improve the recruitment and preparation of students, particularly those from underrepresented groups, through participation in a two-week summer enrichment workshop that increases students' knowledge in a variety of STEM areas. Students who had just completed either the 10th or 11th grade were recruited by email and telephone calls to guidance counselors, STEM teachers, and principals. The program website and social media were also used as recruitment tools. The students admitted met selection criteria based on high school transcripts and an essay about their reasons for wanting to attend. 29 students were accepted into the program (19 male, 10 female). One male student who completed only one week of STEM-SEP decided to quit the program to start a summer job. His parents supported his decision. Of the 28 who completed the program, 15 were of a minority (Asian, African American, etc.) The participants were from 12 area high schools and one home-schooled student.

STEM-SEP was held on the campus of Penn State Harrisburg from June 13, 2016, to June 24, 2016. The sessions offered active learning through participation in laboratory-style learning and team activities[6-9]. Such activities have shown to improve retention of women in engineering majors, a key feature since female students disproportionately change majors from engineering into other fields of study[10-11]. The following sections describe the program activities and present evaluation results.

Workshop Schedule

At the welcome session, parents and participants met the faculty and staff. Each student received a welcome package with a TI-80 calculator, T-shirt, drawstring backpack, notebook, pens, small football and Frisbee. Pictures were taken with the University mascot. These pictures were mounted with a certificate of completion and presented to each student at the closing ceremony. Lunch and snacks were provided each day. Table 1 shows the workshop schedule.

Table 1. STEM-SEP Workshop Schedule

STEM Summer Enrichment Program (STEM-SEP) Schedule

Lunch 12pm – 1pm

		9-12 noon	1-4 PM
Week 1	**M**	Registration, Welcome, Photo	Math Applications
	T	Math Applications	Physics Applications
	W	Chemistry Applications	Field trip 1: Diagnostic Lab
	R	Biology 1	Biology 2
	F	Computer Science 1	Computer Science 2
Week 2	**M**	Civil Engineering 1	Civil Engineering 2
	T	Electrical Engineering 1	Electrical Engineering 2
	W	Mechanical Engineering 1	Mechanical Engineering 2
	R	Field Trip 2: Steel Plant	Preparing for College Work on presentation
	F	Work on presentation	Presentations & Awards

The program began with one week of science sessions: mathematics, computer science, physics, biology, and chemistry. The first week concluded with a field trip to the Pennsylvania Animal Diagnostic laboratory (PADL). PADL is a state government facility whose primary mission is to keep the state's wildlife and farm animals healthy. The second week was devoted to engineering: civil, mechanical, and electrical. That week included a trip to a local steel manufacturing facility that takes steel from raw material to finished rail products. The week concluded with students

working in pairs to present prepared talks for the faculty and their families. They described their favorite learning experience during the workshop and how they think what they learned might impact their future career plans. The following paragraphs describe each session.

Mathematics -- The mathematics sessions introduced cryptography and multi-dimensional space. Cryptography addresses how we send information securely, even when we know people are listening. Students learned how prime numbers and modular arithmetic revolutionized modern cryptography. In the other session, students explored a hyperspace world with four spatial dimensions and built a hypercube.

Physics -- Students investigated scientific questions related to force and energy through a number of hands-on activities in teams of three. Each team reviewed and applied Newton's Laws of Motion in their design and testing of a restraint system for an egg acting as a passenger in a toy car that was released down a ramp to crash into a wall. Students learned the basics of solar energy and each team assembled an electric motor solar-powered car. Through trial and error, teams determined the lighting conditions for optimal performance. Finally, information presented about force and pressure was demonstrated and tested through the launching of water bottle rockets. Water volume and air pressure were varied to observe the effects on maximum altitude. Each student left with an assortment of things that jump, spin, balance and fly.

Chemistry -- What are Polymers? Where can we find them? What are they used for? From DNA to Styrofoam, students enjoyed a hands-on experience synthesizing and breaking down various types of polymers. Activities included a gloop synthesis, carbohydrate breakdown, styrofoam structure, and DNA extraction. Students were introduced to concepts in biochemistry and organic chemistry.

Biology -- Students participated in activities to promote a greater appreciation for the world of biotechnology, pharmacy, and forensics. Students were exposed to the Biofuls Laboratory, a world-class biotechnology facility. They participated in an exciting laboratory-based scientific investigation using state-of-the-art DNA profiling techniques. In addition students performed a problem based learning exercise to understand the mechanisms of molecular biology. The second part of the day students explored nature's pharmacy through a taste, touch, and feel experience.

Computer Science -- Participants learned the basics of programming in Java, as they created bots that played a video game. At the end of the session, students pitted their bots against each other in a Bot!Battle! tournament. The Bot!Battle! system was developed by Computer Science students at Penn State University-Harrisburg as part of their Senior Capstone projects.

Civil Engineering -- Past, present, and future of construction materials: Think the General Motor's commercial "It's not your father's Oldsmobile." First, students learned how materials have evolved. They explored materials used in today's construction through hands-on testing and explored potential materials of the future. Then in Session 2, they built a bridge while learning the basic concepts of design. In a hands-on friendly competition, teams tested their bridge building skills and understanding of design concepts. The session also addressed civil engineering challenges of the future.

Electrical Engineering -- Students learned about biological behaviors such as light seeking or light avoidance. They then learned how that behavior can be replicated in a simple robot. They described the design of the robot and how the individual components work. They also learned how to solder, assemble the robot kits, and make them work. Finally, students were allowed to make improvements in their robots for better speed and efficiency.

Mechanical Engineering -- Students designed, tested, and redesigned paper airplanes to improve on their performance. A competition was held to determine which design produced the maximum flight distance. Mechanical engineering topics introduced during this session include: forces, fluid mechanics, efficiency, and sustainability. In the second session, students got hands-on experience with 3D printing. How does a 3D printer work? What are the different types of printers and materials that can be used? The steps from conceptual design to 3D modeling, preparing the CAD file for print, and finally 3D printing was demonstrated using real life applications. Students had the opportunity to 3D print different items.

The last two sessions were a "Preparing for College" program presented by staff from the Multicultural Affairs department and preparation of a presentation about what the students learned. The students created their presentations in pairs. They chose their partner based on their shared interests and future plans. They presented to faculty, staff, and family members at the closing ceremony. After all the participants had presented, a framed certificate of completion was presented to each one that included their photo from the first day with the university's mascot. A group picture of workshop participants is shown in Fig. 1.

Figure 1. Group picture of workshop participants

Program staff included 11 faculty members and three university student assistants: 2 undergraduates and 1 graduate student. The program staff were culturally diverse (Asian, African-American, Middle-Eastern, etc.) with 5 female and 9 male staff members. Each session instructor met with the student assistants for two-four hours prior to the workshop to train the assistants to ensure that adequate help would be available during the sessions.

Workshop Evaluation by Participants
All workshop sessions, the field trip and the workshop overall, were evaluated by participants. The questions from the feedback forms for each of the sessions, field trips and overall, are presented below. The corresponding results are summarized in the results section.

The individual sessions were evaluated immediately after each session as follows:
Please complete the following questions: Participants were asked to choose from these 5 answers: Strongly agree, Agree, Not sure, Disagree, Strongly disagree

1. This session added to my understanding of STEM.
2. I learned a lot from this session.
3. This session was fun.
4. Supplies and training materials were easy to use.
5. As a result of this session, I am more interested in STEM.

Participants had space to comment also: "Please use the following space to write any additional information you would like to share with us regarding this session."

The field trips were evaluated as follows:.
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. _____

The workshop overall was evaluated on the final day of the workshop as follows:
Please complete the following questions. For the individual sessions participants could answer Excellent, Good, Fair, or Poor. Questions 3 to 5 had response choices of Strongly agree, Agree, Not sure, Disagree, Strongly disagree.

1. Rating of individual workshop sessions: Math, Physics, Chemistry, Biology, Computer Science, Civil Engineering, Electrical Engineering, Mechanical Engineering, Industry Visits/Field Trips, Preparing for College, Project presentations and awards.
2. My favorite workshop session was: _____
3. I am pleased that I attended this workshop.
4. I would recommend this workshop to a friend or sibling.
5. Attending this workshop increased my confidence in my ability to succeed in college.
6. How could the workshop experience be improved for future participants?
7. What was the best thing about this workshop?
8. What was the worst thing about this workshop?
9. Please provide any additional feedback that you wish to share with the workshop organizers.

Results from Participant Workshop Evaluations

The evaluation results were calculated from the scores to present them as percentages. The highest score of 100% would indicate that all the students had Strongly Agreed with all questions. The results from the 5 questions asked at the end of each session are presented in Table 2 and Figure 2.

Overall, the sessions achieved their goals and were very well received by the students. As shown in Table 2 and Figure 2, the students expressed that they learned a lot, had fun, understood STEM topics better, and were more interested in STEM as a result of the individual sessions. The materials and supplies were generally easy to use with the computer science and the mechanical engineering session on design (ME 2) needing some improvement in that area.

An unexpected result was that the students bonded quickly. They created a group chat that they used during breaks and at home. Spontaneous frisbee and soccer games were organized by the students during daily lunches. The less athletic of the participants chose to cheer for the players. Contact from some students or parents in the weeks afterwards indicated that some of the friendships continued after the end of workshop.

As might be expected, after all the sessions were complete, the final evaluations reordered the session preferences as shown in Figure 3. At the end, the electrical engineering session was the most popular with 13 of 28 students listing it as their favorite. They really enjoyed learning to solder. Mathematics and biology tied for 2nd and 3rd place with students. None of the other sessions were even half as often listed as a "favorite".

Table 2. Evaluation results for individual sessions, presented in order by session.

Session	STEM Understanding	Learning	Fun	Material Usability	STEM Interest
Mathematics	93%	94%	89%	92%	90%
Physics	88%	86%	97%	92%	91%
Chemistry	90%	89%	96%	96%	89%
Comp. Sci.	86%	79%	82%	60%	82%
Biology	97%	96%	96%	92%	94%
Civil Eng.	91%	86%	86%	92%	85%
Elect. Eng.	98%	96%	96%	85%	95%
Mech. Eng. 1	89%	87%	91%	96%	88%
Mech. Eng. 2	92%	90%	82%	66%	89%

Workshop Evaluation by Faculty & Staff

All workshop sessions were discussed at the end of the day by the program faculty and staff with an eye toward quality improvement. Over the two weeks, daily contact throughout the sessions allowed the program staff to adjust student teams to keep academic and social activities running smoothly. Each instructor had the freedom to choose the material, within their area of expertise, they considered most advantageous to the students. Comments made to the staff and faculty by the students made clear that the topics and associated hands-on activities were pleasing to the students and augmented their previous high school studies or introduced new ideas to them.

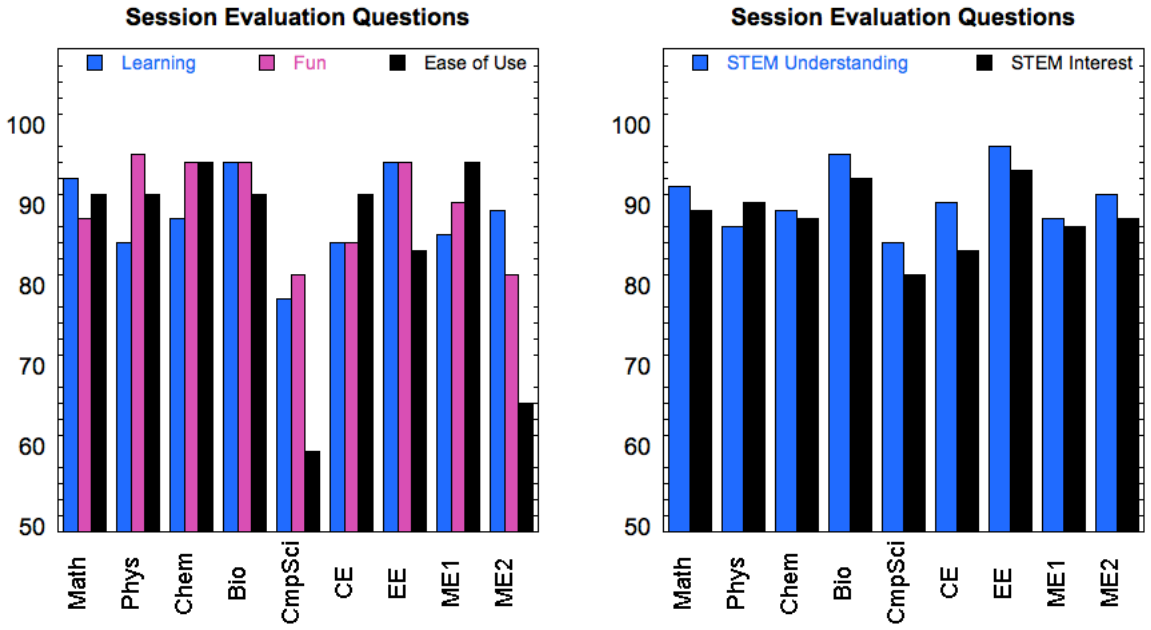

Figure 2. Individual session question results by topic, left to right chronologically.

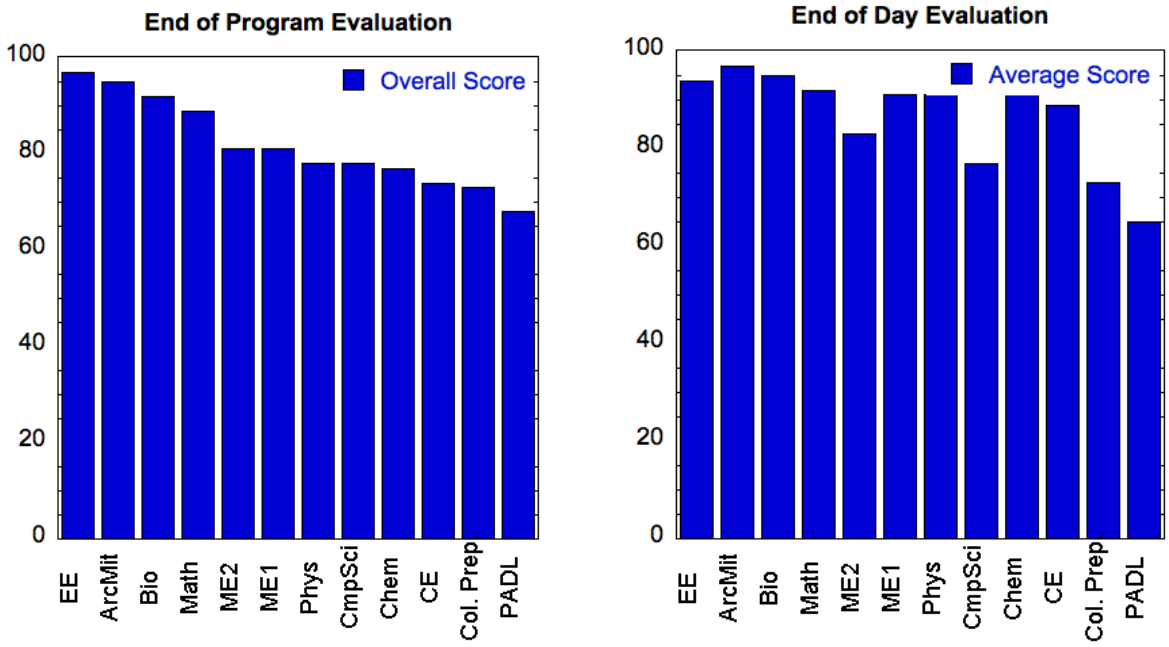

Figure 3. Evaluation results from the end of whole program and the end of each session.

These impressions were supported by the evaluation results. The students interacted extremely well together. Friendships blossomed and a "group chat" was started among the students in the first two days. To prevent social interaction from veering too far from the academic topics, purely social interactions were diverted to the short breaks during sessions and lunch; this worked well. These teenagers were so happy to meet a whole group of their peers who shared

their interests and aspirations. The program has been funded for another year. There will be small changes, but overall the program will retain the same structure and focus.

Other summer programs[7, 12-13] report similar enthusiasm from the participants. Those programs also reported that student evaluations of the sessions and experiences received high marks. During the last year, two parents of 2016 STEM-SEP students communicated that their children are now actively planning on entering an engineering career when previously they had different plans. Data has not yet been collected to evaluate the long-term results for the whole group.

Conclusion

STEM-SEP was successful in achieving its major objectives. 28 participants, 15 of which were from minority groups, successfully completed all workshop activities. Feedback from students shows that the workshop activities were fun and effective in teaching participants about STEM disciplines and career opportunities. Students mentioned the field trip to the sponsor's steel plant in their final presentation and thanked the company for sponsoring the workshop. Several parents talked to the program faculty and staff during the ice cream social after the closing ceremony on the last day of the workshop and thanked them for a well-organized and successful workshop.

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Biographical Information

SUSAN ESKIN

Susan Eskin joined the faculty at the Pennsylvania State University - Harrisburg in August 2013 in the School of Science, Engineering, and Technology. Dr. Eskin moved to Harrisburg to teach physics from the University Park campus where she was a member of the research faculty. Before that she was a member of the Medical School Faculty first at Temple University in Philadelphia and then at West Virginia University in Morgantown. She received her B.S. and M.S. in Physics from the University of Kentucky and her Ph.D. in Nuclear Physics from the University of North Carolina at Chapel Hill. Her experience includes a postdoctoral fellowship at Stanford University and employment with Siemens Medical Systems. Dr. Eskin is a board certified in Magnetic Resonance Physics and has been a contributing member of the American Association of Physicists in Medicine, the International Society of Magnetic Resonance in Medicine, the American Society of Physics Teachers, and the American Society of Engineering Education.

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Rafic Bachnak joined Pennsylvania State University-Harrisburg in August 2013 as the Director of the School of Science, Engineering, and Technology. Previously, Dr. Bachnak was on the faculty of Texas A&M International University, Texas A&M-Corpus Christi, Northwestern State University, and Franklin University. He received his B.S., M.S., and Ph.D. degrees in Electrical Engineering from Ohio University. His experience includes several faculty fellowships at NASA and the US Navy Laboratories, and employment with Koch Industries. Dr. Bachnak is a registered Professional Engineer in the State of Texas and has been active in several professional organizations, including IEEE, ASEE, ISA, and ABET. He is currently serving as EAC/ABET Program Evaluator.

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