Engaging Underrepresented Students in Engineering through Targeted and Thematic Summer Camp Content (Work in Progress, Diversity)

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The Soaring High in Engineering (SHE) camp at the University of Arkansas was designed to integrate recent advances in engineering education research with a novel camp format to create a weeklong engineering immersion experience for female students who recently completed 7^{th} and 8^{th} grades. In developing this camp, we considered the interests of the student participants, the strengths of the undergraduate students who assisted in content creation and facilitation, and recent research on engaging women and other underrepresented students in engineering to provide participants with the most meaningful, enjoyable camp experience. We also assessed whether the camp outcomes, including interest in engineering or other STEM careers, were increased by developing the camp with self-reported student interests in mind and developing camp content around a single accessible, real world theme.

A major goal of the University of Arkansas College of Engineering summer camps is to reach as diverse a group of students as possible. Although any female student in the eligible grades was welcome to apply to the SHE camp, we also used a targeted mailing campaign to recruit students from a nearby school district where over 60% of the students are members of an underrepresented ethnic minority [1]. As a result of these efforts, there were 58 applicants for the 40 available camp spots. Fifty-four percent of applicants were members of the underrepresented minority groups (40% Hispanic, 9% Native Hawaiian/Pacific Islander, and 5% African American). In addition to the ethnic diversity of our applicants, the selected participants also had public (89%), private (5%) and homeschool (5%) educations, as well as a wide range of academic abilities (68% of applicants had 3.7 GPA or higher; 11% had a 2.9 GPA or lower). As a result of this diverse applicant pool, we sought out the engineering and STEM education literature on the best ways to create interest, understanding, and excitement among both women, underrepresented minority groups, and women who belong to these groups.

Engaging Diverse Women in Engineering

Underrepresented groups in engineering such as women, especially women who belong to underrepresented minority groups, contribute diverse experiences and perspectives in STEM classroom settings but face many barriers to their success [2]. Women who belong to underrepresented minority groups can be hesitant to draw attention to themselves or worry about being conspicuous when participating in STEM education [3]. Many of these women are also frustrated when science is portrayed as ethnically or gender neutral when their own experiences have shown them it is not [4]. Another barrier for engaging underrepresented women in STEM fields is related to the way science is taught. Science education often does not focus on connecting the coursework to the world outside of the classroom [5]. Using inquiry- and problem-based learning allows students to realize the real world implications of what they are learning and, therefore, motivates students to understand the material more easily, encourages collaboration, and helps students develop higher-order cognitive skills which are necessary for success in STEM fields [6]. Female students and members of underrepresented minority groups in particular have been shown to be more enthusiastic about problem-based learning in STEM education [6]. Acknowledging and overcoming these fundamental barriers can sometimes be more easily accomplished through more informal STEM education settings, such as summer camps, than in traditional classroom settings [7].

Research has also shown that women and underrepresented minorities respond better to STEM education in settings where the task are contextualized, the projects that are socially-relevant, and when activities are multi-media and hands-on [6], [8], [9]. Studies have shown that women are typically more attracted to projects that seek to improve society and consider this factor when choosing their college majors [10]. Several schools with engineering programs devoted to improving society have large majorities of women enrolled in these programs, which differs tremendously from typical engineering programs [11]. Effectively communicating that the overarching goal of engineering is to develop tools to benefit and improve society appears not only to increase the number of women pursuing an engineering education, it also portrays STEM fields in a better light for the population at large [11].

Developing the Camp Content

Before developing the camp content, we wanted to develop an understanding of both the demographic composition of our participants as well as their motivations for applying to attend the SHE camp. By reviewing the applications, we were able to identify student interests as well as some misconceptions about engineering that could be addressed during the course of the camp. Among these applications, we found that 53% of Hispanic students were interested in medicine generally or in becoming doctors, nurses, or biomedical engineers in response to at least one application question. Only 29% Hispanic applicants identified biomedical engineering, specifically, as a field they were interested in or aware, but 47% mentioned medicine or nursing. Meanwhile, only 23% of white applicants indicated an interest in biomedical engineering, medicine, or nursing. Most of the white applicants instead identified more ‘traditional’ engineering interest (e.g., building things, robotics, circuits) as reasons for attending the summer camp. This disparity in interests between ethnic groups suggests that the white students may have had more prior exposure to engineering concepts, while the Hispanic students used their real world experiences to identify interests and future careers. Furthermore, specific answers revealed that Hispanic students did not inherently link engineering to any medical careers or applications.

With this application data and research in mind, we developed our camp, “Outbreak! Engineering an Epidemic,’ with inspiration from a similar Engineering is Elementary curricular unit [12] (Boston Museum of Science 2016) and activities from Teach Engineering [13]. Instead of focusing solely on biomedical engineering content, however, we created activities that also highlighted aspects of multiple fields of engineering in addition to activities that incorporate computer science concepts and effective STEM communication strategies. By developing the camp in such a way, we were able to expose students to the interdisciplinary contributions of multiple fields of engineering to the medical field and also show precise ways that engineers, and themselves as camp participants, could utilize their individual strengths to combat global issues.

The SHE camp was designed to simulate the steps that would be undertaken as part of an epidemic response, and students were tasked with a series of disaster response activities, in addition to receiving instruction in basic microbe and epidemic behavior. When developing the projects that comprise the camp, we wanted the students to be constantly engaged in solving the larger problem. To do this we created a curriculum that took the students through the progression of an epidemic as it spread from the local, to regional, to national, and finally to global scales.

Each day began with camp participants receiving 'news bulletins' that informed them about how the diseased progressed and the steps they needed to take to combat it.

One major goal of our engineering summer programs is to authentically expose students to a wide variety of engineering fields, so we were careful to ensure that projects were actually representative of the intended fields. In order to do this, we communicated with faculty and asked graduate and undergraduate students who were majoring in these fields to think of projects they might have completed in a lab or class that could be related to our epidemic theme and distilled into an activity appropriate for 7th and 8th graders. We utilized female undergraduate engineering students to develop and facilitate the camps. This provided the students with the unique opportunity to highlight activities that reflected their degrees and helped ensure that the projects chosen, accurately represented their field. In addition, this experience exposed the undergraduate students to other engineering fields and challenged them to develop content outside of their areas of study. To do this, the students formed interdisciplinary teams with other students and faculty members that brainstormed ideas for content. They also as acted as test groups for verifying the effectiveness of the content and presentations. Through this process, the student facilitators developed and demonstrated proficiency in each topic area in order to teach the camp content to the camp participants.

Camp Content

Within the camp theme 'Outbreak! Engineering an Epidemic,' four subsets of activity types emerged: activities that exposed students to the structure and function of microbes, activities that explored the ways in which epidemics spread through populations, engineering design and building activities, and activities that allowed students to communicate their research and designs with others.

<table>
<tr><th></th><th>MONDAY</th><th>TUESDAY</th><th>WEDNESDAY</th><th>THURSDAY</th><th>FRIDAY</th></tr>
<tr><td>9:00 AM</td><td rowspan="2">Introduction to Problem</td><td rowspan="3">Multiplying Activity (Computer Science)</td><td rowspan="4">Mask (Biomedical)</td><td rowspan="4">Ground Water Detective (Biological/Civil)</td><td rowspan="10">The Best Defense/Is a good offense… (Biomedical)</td></tr>
<tr><td>9:15 AM</td></tr>
<tr><td>9:30 AM</td><td rowspan="3">Campus Tour</td></tr>
<tr><td>9:45 AM</td><td>BREAK</td></tr>
<tr><td>10:00 AM</td><td rowspan="6">Disease Modeling (Computer Science)</td><td>BREAK</td><td>BREAK</td></tr>
<tr><td>10:15 AM</td><td>BREAK</td><td rowspan="5">Quarantine Box (Mechanical)</td><td rowspan="5">Ground Water Detective (continued)</td></tr>
<tr><td>10:30 AM</td><td rowspan="4">Bacteria Busting Part 1 (Industrial)</td></tr>
<tr><td>10:45 AM</td></tr>
<tr><td>11:00 AM</td></tr>
<tr><td>11:15 AM</td></tr>
<tr><td>11:30 AM</td><td colspan="5">Lunch</td></tr>
<tr><td>12:30 PM</td><td rowspan="4">Bacteria Busting Part 2 (Industrial)</td><td rowspan="4">Social Data and Disaster Response (Communication in STEM)</td><td rowspan="7">Quarantine Box (Mechanical)</td><td rowspan="4">Hospital Optimization (Industrial)</td><td rowspan="16">Obstacle Course/Celebration</td></tr>
<tr><td>12:45 PM</td></tr>
<tr><td>1:00 PM</td></tr>
<tr><td>1:15 PM</td></tr>
<tr><td>1:30 PM</td><td rowspan="4">Bacteria Busting Part 3 (Chemical)</td><td rowspan="7">Thermometers (Electrical)</td><td rowspan="5">Informing the Public (Communication in STEM)</td></tr>
<tr><td>1:45 PM</td></tr>
<tr><td>2:00 PM</td></tr>
<tr><td>2:15 PM</td><td>BREAK</td></tr>
<tr><td>2:30 PM</td><td>BREAK</td><td rowspan="8">Biohazard Suit (Biomedical)</td></tr>
<tr><td>2:45 PM</td><td rowspan="7">Tracking a Water Virus</td><td>BREAK</td></tr>
<tr><td>3:00 PM</td><td rowspan="6">Drug Delivery Systems (Chemical)</td></tr>
<tr><td>3:15 PM</td><td>BREAK</td></tr>
<tr><td>3:30 PM</td><td rowspan="4">Spreading Germs/ Going Viral</td></tr>
<tr><td>3:45 PM</td></tr>
<tr><td>4:00 PM</td></tr>
<tr><td>4:15 PM</td></tr>
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Table 1: An overview of the camp schedule that identifies the timeline of activities as well as their relation to specific fields of engineering.

Before being able to combat the spreading epidemic, students had to first have a working knowledge of the microbes that were responsible for the disease. Since this was an engineering camp, we tried to introduce this critical content in creative ways that allowed for the application of engineering principles. An overview of activities is shown in Table 1. The first activity, Bacteria Busting, allowed students to tour campus with an eye toward identifying the places where people congregate or pass by with frequency. Using these observations, students used strategies from industrial engineering to develop a bacteria sampling strategy and then collected samples at the identified locations. The samples were placed on agar plates and the bacterial colonies were allowed to grow throughout the camp week. In another activity, students were shown a large-scale model of a receptor cell and then tasked with designing a model virus that would attach to the cell. In addition to teaching students about the general structure of the virus, this activity required concepts from mechanical engineering to design virus models that had complementary structures to the cell models. In a final activity, participants were asked to use the same concepts as before, but we tasked with modifying their virus or the cell model to prevent infection, thereby learning about the way in which some antiviral treatments work.

Throughout the weeklong epidemic, students also saw how it spread from a single small community to a global phenomenon, learned about various ways that diseases spread, and the strategies used to prevent or slow the spread. Students first participated in a water exchange activity to model disease spread through a population and then applied concepts from computer science to manipulate computational models of disease spread. They also had the opportunity to use a scaled-down industrial engineering challenge activity to determine the layout of a hospital in such a way that patients most at risk of infection (infants and the elderly) had a reduced probability of exposure to the disease. Finally, they used hydrologic concepts from civil engineering to understand the ways in which a water-based microbe might move from one area of a community to another.

After these basics of disease biology and transmission were established, students were asked to design, build, test, and redesign epidemic battling technologies. In the quarantine box activity, students worked as mechanical engineers to innovate a simple design for a box that would prevent human contact with a ‘pathogen’ while allowing manipulation of that pathogen. The sanitary mask and biohazard suit activities allowed the camp participants to work as biomedical engineers by asking them to design systems to keep healthcare professionals from becoming infected by the disease. In these activities, students learned about the importance of lab safety, simple thermodynamics, and how to test and redesign to achieve maximum efficacy. Additionally, students applied concepts from computer and electrical engineering by building and testing thermometers using an Arduino Uno kit. Finally, students were asked to use limited materials to develop capsules capable of delayed-release drug delivery.

In addition to the STEM principles introduced through the camp activities, we also wanted to reinforce the importance of being able to develop effective communication strategies to keep the public informed and engaged. To this end, we had students create both social media campaigns and public service announcements using other media to educate the ‘public’ on steps they could take to stop or slow the spread of the epidemic. As part of these activities, students were also tasked with identifying the forms of media that can reach the most people.

Camp Outcomes

We were able to assess camp outcomes using identical pre- and post-camp surveys. These surveys were developed by Eric Specking and have been used since 2015 to assess the outcomes of other summer camp formats. The surveys asked students to gauge their interest in, understanding of, and excitement about various STEM topics (engineering, math, and technology) as well as specific fields of engineering using a five-point Likert scale (see Table 2 for a list of fields, specific scale used, and results). Preliminary survey analyses reveal that student responses increased in *all evaluated areas* after their camp experiences. Closer analyses of the aggregate survey results reveal some interesting trends related to attitudes about specific fields of engineering.

	Engineering	Math	Technology	Biological	Biomedical	Chemical	Civil	Comp Sci	Computer	Electrical	Industrial	Mechanical
	Interest (0 = no interest, 5 = strong interest)											
Pre Survey Mean	3.81	3.68	3.97	2.81	2.97	3.00	2.61	3.19	3.26	2.87	2.74	2.97
Post Survey Mean	4.10	3.79	4.00	3.24	3.83	3.83	3.25	3.62	3.52	3.52	3.31	3.18
Difference	0.30	0.12	0.03	0.43	0.86	0.83	0.64	0.43	0.26	0.65	0.57	0.21
	Understanding (0 = poor understanding, 5 = excellent understanding)											
Pre Survey Mean	3.23	4.97	4.29	1.77	2.29	2.39	1.87	2.52	2.65	2.16	1.97	2.26
Post Survey Mean	4.86	4.96	4.86	4.48	4.97	4.62	4.76	4.43	4.36	4.36	4.50	4.14
Difference	1.63	0.00	0.57	2.71	2.68	2.23	2.89	1.91	1.71	2.20	2.53	1.88
	Excitement (0 = no excitement, 5 = very excited)											
Pre Survey Mean	4.68	4.55	4.87	3.23	3.74	4.00	2.61	3.68	3.94	3.10	2.90	3.45
Post Survey Mean	5.24	4.86	5.21	4.36	4.90	4.90	4.10	4.52	4.41	4.69	4.31	4.24
Difference	0.56	0.31	0.34	1.13	1.15	0.90	1.49	0.84	0.48	1.59	1.41	0.79

Table 2. A summary of responses (means of all responses) from the pre- and post-camp surveys.

Student understanding of biological, biomedical, chemical, civil, electrical, and industrial engineering increased most more than two points (from poor/fair to good/very good) from pre- to post-survey. All of the other fields of engineering assessed also saw at least one point increases, as well. Student interest in all fields increased, with biomedical engineering seeing the largest increase: a pre-survey mean of 2.97 to a post-survey mean of 3.83. This result is not unsurprising given the stated interests of the camp applicants. Finally, excitement increased most at least one point for biological, biomedical, civil, electrical, and industrial engineering. These results reveal an unsurprising trend: the most positive student experiences, as reflected by survey results, were in the fields of engineering where we either had multiple activities or the camp activities were especially interactive or compelling.

Future Directions These results from surveys conducted during the pilot year of the SHE context-oriented camp appear to indicate that the format is successful and has encouraged us to develop similar camps for all age levels and populations we reach through our summer programs. Despite these encouraging results, we have several ideas for future improvement that will be implemented in Summer 2018. First, we plan to modify the camp activities to align with the [state science standards] to both add value for students and for teachers who may wish to implement some components of the camp in their own classrooms. We also plan to improve the quality of some activities, including implementing 3D printing of virus models and antiviral adjustments. Finally, we are finalizing assessments designed to obtain more specific information about which parts of the camp students found most engaging, how the overall experience has modified--or not--their college or career interests, and get student input for future iterations of our engineering summer camps. We have presented our SHE camp development process, demographics, content, and results with the hope of engaging other organizations who host similar programs in dialogues about the issues identified above.

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