Board 177: Sustainability Focused Pre-college Engineering Education for Building a STEM Pipeline – Work in Progress

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Introduction

Engineering education programs prepare graduates to meet the required workforce needs in various disciplines and develop the next generation of experts to advance technology for solving real-world problems. Emphasis over the last several decades has been to prepare adequate qualified engineers to meet the demand in the workforce. Most of the tech-related industries focused on creating a STEM pipeline by raising awareness in K-12 students and supporting motivation and education efforts for this purpose. Higher education institutions supported this initiative by engaging engineering students as mentors and role models for K-12 children particularly from underserved communities. Youth were engaged in hands-on activities including robotics, coding or other interesting topics either in after-school programs or through summer camps [1,2]. However, a major real-world problem deserving immediate attention at this time is building a sustainable future for all of humanity. Upon surveying 20 top-tier Higher education institutions literature concludes [3] that "leaders in STEM education who will be expected to produce graduates that develop innovative and creative solutions to the world's most complex problems are making great strides to include sustainability concepts within their curriculum, both on and off campus." A wider adoption of sustainability in engineering curricula is one of the greatest focus today. This is evident from efforts of several agencies and institutions to act as change agents. Engineering for One Planet (EOP) is an initiative to transform engineering education and equip all future engineers across all disciplines with the fundamental skills and principles of social and environmental sustainability [4]. It is also important to raise awareness among pre-college students about sustainability and STEM to prepare a new generation of change agents. Informing the need for a sustainable future for all and educating K-12 youth on the Sustainable Development Goals (SDGs) of the United Nations [5] through topics on energy and hands-on activities is one of the key components of this endeavor.

Recently several industry partners, some of whom are renewable energy providers support the sustainability initiative by funding higher education institutions and K-12 students. These efforts are primarily designed to address the needs of underserved as well as diverse populations and to prepare the next generation of scientists, technologists, engineers and mathematicians who will have the knowledge and ability to achieve a sustainable future for all [6,7]. One of these initiatives aims at advancing sustainability awareness through efforts to enhance students' understanding of science and technology and to inspire them to think differently about energy. Through the E2 Energy to Educate grant program, they offer students from sixth grade through college, opportunities to address the energy challenges of today and tomorrow. Teachers who often do not have the materials for hands-on activities for STEM and Sustainability can receive support from such initiatives in collaboration with higher education institutions. With support from Constellation Energy [6], the authors of this work in progress have attempted to educate and train over two hundred middle school students of the local underserved community on sustainability issues, particularly on those related to energy and environment through relevant hands-on activities. The following sections describe the materials and methods applied in educating the underserved community of students and teachers and its potential impact.

Materials and Methods

The faculty involved in the project began planning activities in the Fall of 2021 in partnership with local K-12 schools and after-school community centers. The goal of the project was to deliver curriculum content and hands-on activities that are relevant to sustainability and energy. During discussions at the planning events, Middle school science teachers to 7th and 8th grade informed the project team that their students have been introduced to renewable energy and wavelengths. This information helped align the curriculum and meet the goals of the project and to build topics for presentations and hands-on activities. A schedule that suited all partners was planned. Students from the university school of engineering who will serve as mentors were recruited. The participating mentors were called Fellows of the project. Faculty involved in the project designed the curriculum and purchased all equipment and supplies needed to deliver the program. While the ongoing pandemic, and a surge of positive cases of COVID from November 2021 through January 2022, made it more challenging than anticipated to coordinate schedules, we worked diligently with the K-12 teachers and the Fairfield University's Center for Social Impact to finalize our plans and promptly began the implementation of the program in Spring 2022.

During early Spring, the project faculty members, held an Information Session for the Fellows. At that session their roles and responsibilities as mentors was discussed. Fellows were probed on how to keep science and engineering concepts simple and easily comprehensible for the middle school children. They were asked to look back on what made a challenging science concept simple and easy to understand during their middle school years. This got them creative on how to keep it simple while delivering content and be prepared to interact with mentees through simple questions that will set them thinking. The benefit of hands-on activities that will engage middle school mentees as well as excite them was discussed. Faculty then held a Training and Information Session to introduce our student Fellows to the topic of sustainability, the UN's Sustainable Development Goals. In addition, training regarding the hands-on experiments were provided. A set of draft lecture slides were provided to the students by project faculty. During the following weeks, Fellows and faculty members interacted frequently to improve the lecture materials and the methods of delivery and organized the parts and supplies for the hands-on activities. Another important requirement was the delivery of content in Spanish for one section of middle school students that was a bilingual class. One Fellow with knowledge of Spanish, worked on translating the lecture material with assistance from a school teacher. The project team also created a pamphlet that provided useful, practical information about sustainability practices including a crossword puzzle for students.

The team visited local middle school in March and April 2022, working directly with over 125 students over the course of the spring. Our partnership with community center brought the total number of participants to over 200 students. Table 1 indicates the number of participating students in each group of 7th and 8th grades and students in the after-school program and their meeting patterns. Two teachers who teach the students in these grades from the school participated in the project. As evident from Table 2, 91% of the student served belong to underrepresented minority.

Table 1: Number of students served, their grades and meeting patterns

Cesar Batalla School	**Number of Students and grade**	**Number, duration of meeting**
Group A	22 students (8th grade)	2, one-hour meeting
Group B	20 students (8th grade)	2, one-hour meeting
Group C	29 students (8th grade bilingual)	2, one-hour meeting
Group D	24 students (7th grade)	2, one-hour meeting
Group E	19 students (7th grade)	2, one-hour meeting
Group F	29 students (7th grade bilingual)	2, one-hour meeting
Wakeman Boys and Girls Club	125 students (Mixed grader in after-school activities)	10, one-hour meeting
Total	268 students	22, one-hour meeting

Table 2: Percentage of Ethnicity served at both locations

Ethnicity	**Percentage***
African American	20.7
Asian-American	1.5
Caucasian	7.5
Hispanic/Latino	68.5
Native American	0.6
Other	1.2
Total	**100**

During these visits, four different activities with relevant information through a presentation were conducted: i) *LED There Be Light*: Taught energy preservation via LED light experiment using breadboards – The goal of the project was to think and examine energy usage and ways to minimize energy consumption, as a sustainable practice. The knowledge of wavelength among the middle school children was weaved into the presentation while explaining the different colors emitted by the LED. A lecture on the story of lamps starting from incandescent lamps to the current state of lighting through energy efficient LED lamps was presented. Following the brief presentation, students assembled on breadboard a simple LED circuit. Next, they assembled on the breadboard LED's with three primary colors (RGB LED) to produce white light. Images of this activity are shown in Figures 1, 2 and 3.

Figure 1: Fellow Presenting

Figure 2: Circuit building mentoring

Figure 3: Testing LED Circuit

ii) *Enlightened by Solar Energy:* Explored solar as an alternative energy source via a solar car experiment – The project goal and knowledge of renewable energy among students was tied together during this activity. A brief lecture on photovoltaics for conversion of energy was presented. In this context, the conversion of energy in solar panels being the inverse of LED was explained. The working of motors and gears was also discussed. Students assembled a solar fan and solar toy car and went into open site to test it. There being sufficient sunlight on the day of the activity that boosted the excitement of mentees and confidence of mentors and teachers alike. Image of the activity is shown in Figure 4.

Figure 4: Presentation and assembled solar toy cars and hand-crank generator

iii) *You Crank Me Up*: Taught alternative energy sources via a hand-crank generator experiment – The principle behind the operation of a generator was discussed and it doing the opposite of a motor was examined through a brief presentation. An activity kit that used a hand-cranked mechanism to generate energy to light up an LED was built and tested. The principle of wind and hydro-electric generation and sources of renewable energy was discussed next.

iv) *Best Practices Database*: Discussed the scientific approach and determined the most appropriate sustainability-related activities – A brief description on how quickly earth's resources are being consumed for energy generation by different countries and the impact of greenhouse gases on climate was presented. Fellows surveyed a web-based questionnaire to mentees that examined their sustainable practices [8]. Renewable energy source such as wind and solar as alternate sources for a climate safe future was discussed. The United Nations Sustainable Development Goals were introduced and an interactive session was held with mentees on positive impact of sustainable practices. In addition, the students were introduced to carbon footprint calculations via an online website and classroom question and answers. They were provided with a brochure that included a website [9] that shows the amount of reduction in greenhouse gases using sustainable practices as well as savings through reduction in energy usage.

Overall, Fellows from the engineering program provided instruction and guidance to students during the experiments. The instructions, while focusing on sustainability and alternative energy technologies, also provided information on important engineering concepts including assembling circuits, gear rotation, energy conversion, force and torque.

Results and Discussion

The activities prepared the most underserved student populations in the local community to understand the science and technology of renewable energy sources and adoptable sustainable practices for a climate safe future. The Fellows primarily conducted the evaluation of the program. They solicited responses to questions posed by show of raised hands from mentees during the final meeting at the school. The questions posed to the students were: i) Do you think Sustainability is important. ii) Did you enjoy the hands-on activities that we did with you? iii) Do you like Science/Engineering more after the hands-on activities? iv) Will you consider pursuing Science or Engineering after graduating high school? Images of the survey recorded in the presence of teachers and mentees is as below (Figure 5). The data collected indicated that all students concluded that sustainability is important and that the hands-on activities were enjoyable.

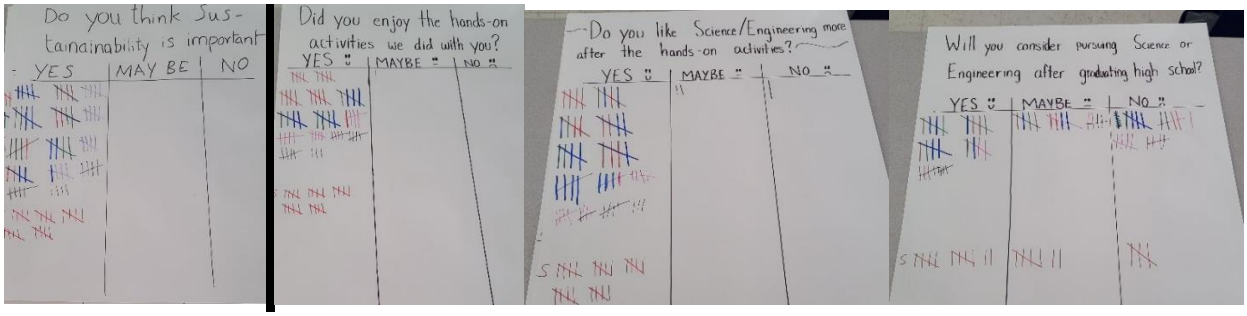

Figure 5: Students responses to questions posed

When asked if science or engineering was more interesting to them after the hands-on activities all but three agreed. However only 47.7 percent said they would consider science or engineering after graduating from high school. Since a pre-survey was not conducted we are unable to conclude the impact of the activities accurately.

The program also enhanced Fellows' ability to show the power of science by identifying the dimensions of public good on issues. By connecting their research across scientific disciplines and communicating scientific research to lay audiences and by developing and teaching inquiry-based lessons Fellows gained valuable skills for future career. They presented their learnings from the mentoring activities at the annual Innovative Research Symposium for undergraduate students at the university. Figure 6 shows an image of their presentation. One of the Fellows noted, "This experience helped me discover creative ways to describe sustainability, alternative energy and electricity. It helped me evaluate topics in new ways and change how I talk about a subject based on my audience."

The middle school students included materials learned from the activities in their annual science posters for their science class. The participating teachers coached them on the poster preparation and suggested that they include a relevant UN sustainable development goal on it. Selected posters of the middle school students were presented at the Innovative Research Symposium of

the university. The presented poster is as shown in Figure 6. Further the teachers received science-specific classroom materials that aligns with the State's science teaching standards, and experimental kits that develop an understanding of science and engineering concepts. The kits included 30 pieces of small 5V dc motor with a mini solar panel to power it. The kit could be used to build a solar toy fan as a hands-on activity. They were also provided with a soldered circuit board for use with their future classes. The kit included RGB LED that can produce different colors of light by varying the currents to red, blue and green elements while being operated with a 9V battery. A mini solar panel powered single color LED circuit was also included in the kit. This will enable teachers to introduce the concept of wavelength of light and its application in technology for future classes.

Figure 6: Poster Presentation of student Fellows and Middle School student poster

An eighth grader when asked said, "Creating the circuit and building the (solar) car was very fun to do. Even though it was sometimes difficult, it taught me that if I kept trying I could do it". Another student added that he would like to build a drone that would help water plants. This way he said he could take care of the environment effectively by pursuing engineering. One student said, "I learned that if you use solar panels, you can power things without harming the earth!" Their teacher stated, "It was so rewarding to see the students' discoveries and their reactions to changing colors of light".

Overall, the team trained the middle school children to recognize their potential as next generation of engineers and scientists and be responsible to shape the energy transition and help achieve the UN's Sustainable Development Goals for a better and more sustainable future for all. For those who were less inclined to choose science or technology, gained knowledge of methods and benefits of adopting sustainable practices.

Conclusion

Through the program, several middle school students performed hands-on activities that focused on sustainability. They had an opportunity to hone their skills as critical thinkers and develop their abilities to relate simple experimental activities to complex environmental issues. The lessons created an awareness among the middle school children on UN Sustainable Agenda and

Sustainable Development Goals and the importance of sustainability and better future for all. They were introduced to the important role that science and technology play in environmental issues. The feedback has shown that they were inspired to initiate changes in their lives and adopt a more sustainable lifestyle. The middle school STEM teachers received materials and instruction for use in their classroom that will benefit future cohorts of their students with high-quality STEM education.

The Fellows learned to communicate scientific concepts to lay audiences by developing and teaching inquiry-based lessons and participated in professional development activities. By providing only a template for several lectures, Fellows worked with faculty on sustainable energy and environment issues and their solutions, innovative teaching methods, networking and leadership opportunities, and hands-on experiences that may encourage them to pursue a career in sustainable energy.

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