Association of Environmental Engineering and Science Professors (AEESP) Foundation Grant

Final Report

Connecting Our Future Scientists and Engineers to Environmentally Friendly Water Treatment Technology in the Post-COVID Era: A Better World Starts with Your Bioreactor

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October 3, 2023

I. Project Overview

The COVID-19 pandemic result in a long-lasting impact, even permanent changes for the K-12 STEM students as the curriculums of STEM programs depends heavily on the active learning strategies, including implementation of hands-on activities, which allows students to discover new concepts and develop new understandings. In this proposed education project, we plan to design a hybrid workshop to reconnect the STEM students in a safe manner to the environmental science and engineering. We also expect to offer a potential solution to narrow the theory–practice gap by engaging K-12 students in project-based activities and highlighting the correlation between their class topics (i.e., science and manufacture/3D design) to real-world environmental issues. The goal of this project is to apply an effective and practical method to educate future generations about sustainable technologies, with the intention of inspiring students' interest in pursuing higher education and becoming future environmental engineers and scientists. The specific objectives of this project include:

1. Objective #1: introduce students to the concept of environmentally sustainable technologies through hybrid platforms (virtual and in-person);
2. Objective #2: engage high school students in learning environmental engineering by conducting project-based hands-on activities in a safe manner;
3. Objective #3: collect data and feedback from students, parents, and teachers to improve the future outreach plan.

To achieve this, the PIs collaborated with the Science & Technology Program and Research Internship Program at the Oxon Hill High School (Maryland). The school has a total enrollment is 1,445, with 98% is minority and 51% facing economic disadvantages. In particular, PIs worked with teachers and program coordinators at the school to ensure the educational materials and resources will be properly developed to adhere to the guidelines set by the Next Generation Science Standards (NGSS), fit their students' need, and effectively disseminated and promoted among students, making the materials/resources greater impact than what is already available online.

II. Major Activities and Achievements

The implementation of this project involved: 1) one hybrid workshop including the tour to the PI Li's research lab at University of Maryland, College Park (UMD); 2) multiple hands-on activities for K9-12 (high school) students; and 3) Final presentation.

1. Workshop

In September 2022, one workshop event was organized at UMD, by the PIs to introduce students, teachers, and program coordinator from the Oxon Hill High school to the sustainable wastewater treatment technologies (**Figure 1a**) through both in-person and virtual participation. In addition, a tour to visit the research labs at Department of Civil and Environmental Engineering (UMD) was conducted (**Figure 1c and d**). During this workshop, hands-on activities (design projects) developed by the PIs were introduced, followed by a Q&A session to answer the questions from the audience. At the end of the workshop event, the research team formed and each group determined their topic.

In addition to the workshop event, in December 2022, a tour was organized by the PIs to invite high school students from the Oxon Hill High School to visit the UMD Terrapin Work which is

home to an expansive collection of additive and subtractive manufacturing resources, including 200+ consumer, research, and industrial grade 3D printers (**Figure 1b**). The aim was to introduce students to the advanced 3D-printing technologies that can be applied for designing and manufacturing biocarrier for biofilm enhancement in wastewater treatment.

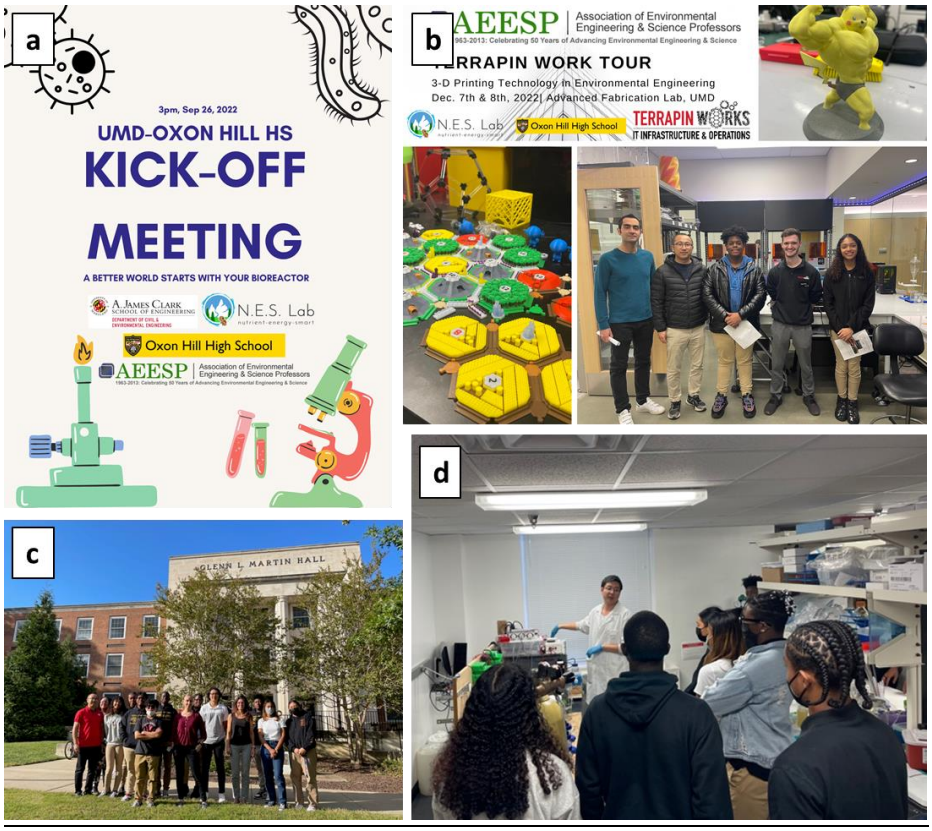

Figure 1. (a) Workshop flyer (kick-off meeting), (b) Tour to 3D Printing lab at UMD, (c) Tour to PI Li's research lab at UMD, and (d) Training of high school students.

2. Design projects

Working closely with the teachers and program coordinator at the Oxon Hill High School, the PIs developed multiple research topics for participating high school students to address three major engineering questions: "What is a cost-effective nutrient removal technology for treating wastewater?", "How to improve the formation of biofilm in wastewater treatment", and "How can automation control assist in modern wastewater treatment processes?".

Team 1 (4 students) explored the current bio-carriers used in wastewater treatment, identified the critical parameters for achieving a rapid and stable formation of biofilm, and designed their own bio-carriers using a free 3D-printing software "TinkerCAD". Students received the training of 3D design at UMD with the tutorial recorded (**Figure 2b**, open access) for future participants as well as broad audience. After they finalized the designs, their bio-carriers (**Figure 2a**) were printed using Prusa MK3S at the UMD Terrapin Work.

Team 2 (4 students) conducted an independent research to understand how biological processes can benefit the wastewater treatment. The students also learned the difference of aerobic and anaerobic microorganisms, and functional microorganisms specialized for removing nitrogen and phosphorus from wastewater, as well as developed operation strategies to start biofilm bioreactors using the biocarriers from either the industry (i.e., K3) or Team 1.

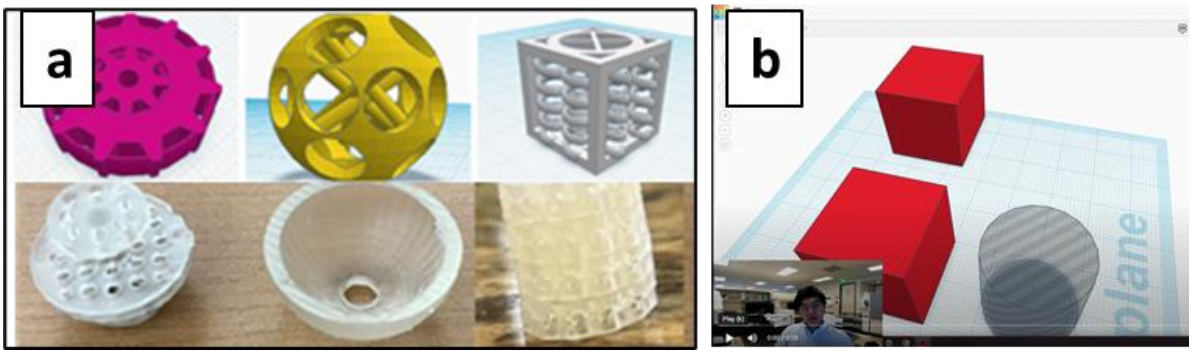

Figure 2. (a) Students designed biocarriers for biofilm formation (design on top, printed on bottom), and (b) developed 3D-printing tutorial videos.

Team 3 (1 student) received the training from PI Li to understand the configuration and design concept of a bioreactor in wastewater treatment, with the emphasis on lab-scale sequencing batch reactor (SBR). An automation control system was developed by the student using Arduino R3 board, air pumps, liquid pumps, and multiple Vernier online sensors (**Figure 3a**). This control system allows users to adjust operation conditions, including duration of each operation phase, aeration condition (air flow), mixing, pH, and volume change ratio. At the end of this project, the student developed an introduction video to introduce the automated SBR and explain its major functions (**Figure 3b**, open access).

During this project period, all participants met the PIs or their lab mentor (graduate student) once per week to acquire the lab training, discuss the results, and report the progress.

Figure 3. (a) Setup of automated sequencing batch bioreactor (SBR) by high school student (Oluwashemilore Bukoye), and (b) developed SBR automation tutorial video.

3. Final presentation

After nine participating high school students completed their project at PIs' research lab, they prepared and presented their results in 2023 Senior Symposium at the Oxon Hill High school. In addition to nine posters (**Figure 4c**), three students delivered their research findings in a plenary oral presentation titled "Biological Wastewater Treatment" (**Figure 4a and b**). More than 500 high school students at different grade levels, school teachers and staff, and students' parents joined the presentation. The presentation was recorded and shared with all students at the Oxon Hill High School. Access to the recording is also available for individuals interested in participating in the Prince George's County Public Schools (PGCPS) Science and Technology Program (S/T). PI Li was invited to join the poster session to communicate with the high school students and introduced the project to the audience.

Figure 4. Final Presentation: (a) high school students and PI Li (from left to right: Malayna Johnson, Dr. Guangbin Li, Oluwashemilore Bukoye, and Bernadette Batong) and (b) high school students presented the project results, and (c) poster session.

III. Conclusions and Future Plans

Although this project was delayed due to changes in the participating high school's schedule and the impact of COVID-19, including outbreaks in the high school during the Fall of 2022, the project was successfully executed, completing all proposed activities and meeting its intended goal. The workshop and final presentation engaged 14 and more than 500 participants, respectively, from a diverse group with majority of the students coming from underrepresented, minority, and low-income populations.

This endeavor produced a range of open-access educational resources (available at project website: https://neslabumd.weebly.com/2022-aeesp-umd-oxon-hill-hs.html), including three tutorial videos on 3D design and one tutorial video on automating sequencing batch bioreactors (SBR). Additionally, a lab-scale automated SBR was developed, offering valuable tools for future outreach projects and STEM students. It should be noted that after completing this project, one of the participating students won the scholarship with Optivs Black Employee Network ($10K) that award individual who identifies as Black and/or African American and is studying a STEM.

Furthermore, the project provided the PIs with valuable experience in designing effective outreach activities and seamlessly integrating them into the curriculum of the Oxon Hill High

School. This was achieved through a hybrid approach involving both in-person and virtual participation.

Moving forward, the PIs plan to sustain this outreach project by continuing the collaboration with the Oxon Hill High School. Presently, they are collaborating with the Science and Technology Internship Coordinators to devise research topics, such as sustainable treatment of emerging organic contaminants, and recruit the second cohort of the research team.

IV. Acknowledgment

This project was supported by the Association of Environmental Engineering and Science Professors (AEESP) Foundation. Special acknowledgment is given to the Science and Technology Internship Coordinator (Mrs. Yolanda King-Davis) at the Oxon Hill High School for collaboration. PIs also thank William Yi (undergraduate student, UMD) for developing the education material on the topic of 3D printer, Emily Speierman (Graduate student, UMD) for team coordination, and Camila Proano and Xiaojue Chen Graduate students, UMD) for providing trainings to the high school students.