AEESP Foundation Grant

Final Report

Developing educational modules for providing K-12 students with basic principles and engineering concepts behind the design of conventional and new water/wastewater treatment processes

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1. Overview

The goal of the proposed project was to develop educational modules for providing K-12 students with basic principles and engineering concepts behind the design of conventional and new water/wastewater treatment processes. Two faculty developed hands-on experiments for 3 levels of audience (K-5, middle, or high school) to pose two science questions related to their research expertise: "Why can't we use seawater in our daily life? (PI: Kim)" and "How can we remove dirt from water? (Co-PI: Yang)". The learning objectives were to understand how impaired water sources affect our daily water uses, apply engineering solutions to remove undesired compounds, and analyze their working principles using water chemistry fundamentals. Education staffs at Clarkson University, Beacon Institute for Rivers & Estuaries (CU-BIRE) were trained in summer of 2021. Some of the developed educational modules were delivered to students from South Middle School in Newburgh during a field trip to CU-BIRE's Water Ecology Center by the education staff. PI Kim delivered several modules to middle school to high school students during Clarkson University Horizons Program held in summer of 2021. Lastly, a pilot program was delivered to K-5 students at North Country Children's Museum in winter of 2021.

2. Major achievements

2.1. CU-BIRE

PIs Kim and Yang traveled to Beacon, NY to train the education staff at CU-BIRE on June 18th, 2021. The training consisted of short presentations to introduce the background by PIs, experiments to demonstrate developed modules for the project, and discussions about the experiments (**Figure 1**).

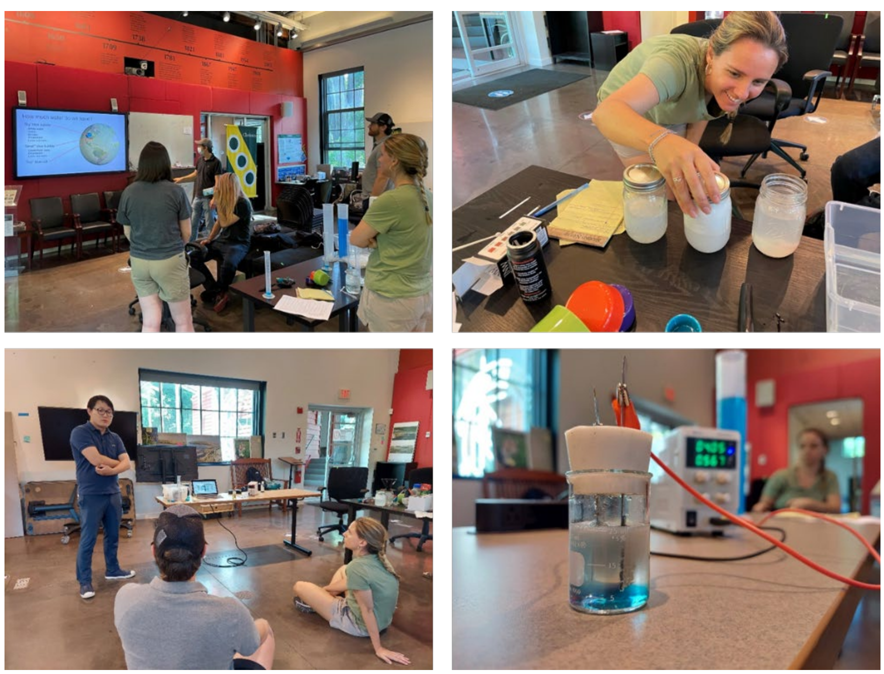

Figure 1. Photos of training the two main science questions of the project on "Why can't we use seawater in our daily life" (top) and "How can we remove dirt from water? (bottom).

For the first science question ("Why can't we use seawater in our daily life?"), we first introduced the distribution of Earth's water, which was visualized by splitting 1 L of water into saltwater and freshwater (adapted from Water Education Posters available from the USGS website). The freshwater was then divided into 4 containers representing the Earth's total freshwater supply in the form of icecaps, groundwater, surface water, and atmosphere/soil. To effectively demonstrate the impact of ionic compounds typically found in saltwater, two solutions were prepared with and without calcium. A high concentration of calcium is found not only in seawater, but also in groundwater. Since water sources in the state of New York is often hard (i.e., high concentrations in calcium or magnesium), we expected to easily engage students using the actual water source of their home. The experiment was to observe the differences when soap powders were added to soft and hard waters. A jar containing soft water without calcium created more bubbles relative to that containing hard water (**Figure 1, top**). The soap water chemistry of hydrophobicity and hydrophilicity was also related to handwashing and Coronavirus. One engineering solution to remove contaminants, including Coronavirus, was to use electrochemically generated oxidants.

As the second part of the project ("How can we remove dirt from water?), we demonstrated the use of an electrochemical system to destroy a dye from water (**Figure 1, bottom**). In the first set of experiments, a IrO_2 anode coupled with a stainless steel cathode was immersed in tap water and water amended with different concentrations of NaCl. 10 V was applied between anode and cathode to observe the current response in tap water (low conductivity) and salt amended electrolyte (high conductivity with high current). The concepts of water conductivity, electrochemical circuit, internal resistance, and overpotential were explained. In the following experiments, the same electrolytic reactor was used to treat water spiked with food dye. Water spiked with NaCl showed the fastest discoloration of food dye due to the production of chlorine via chloride oxidation reaction. By showing this evidence, the principles of electrochemical oxidation and the concept of reduction potential were elaborated. Furthermore, we introduced the basics of chlorine chemistry (pC-pH diagram, pKa, and hydrolysis of chlorine gas) and extended the discussion to chlorination and other disinfection technologies.

One of the developed modules on the water distribution was delivered to 100 6th grade students from South Middle School in Newburgh during a field trip to CU-BIRE's Water Ecology Center in the fall of 2021 (**Figure 2**). The demonstration illustrates the low availability of freshwater resources versus salt water on earth. Students then created water filters to be prepared for if they ever need to procure water on their own from a nearby water source. The lesson ended with establishing an action plan for conserving water in their daily lives.

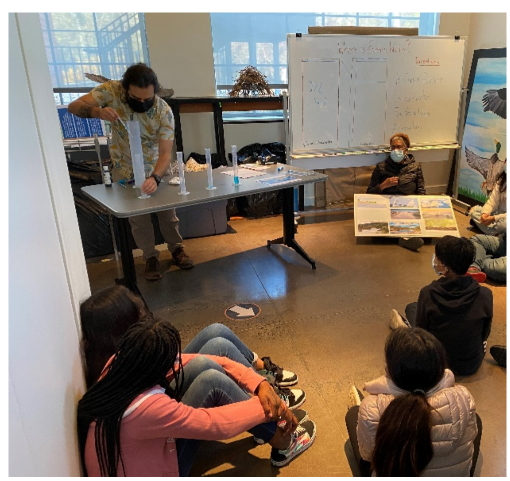

Figure 2. Photograph showing the demonstrating water distribution on the earth to students.

2.2. Clarkson University Horizons Program

As an instructor of Horizons Program held in summer 2021, PI Kim adapted some of the developed modules in his Water Science/Water Purification section (**Figure 3, top**). The total number of participants was 51 in 7th, 8th, and 9th grades (86.3% were female), and these students were from 22 school districts. On day 1, I engaged students with the water distribution and soap bubble experiments mentioned above. On day 2, students made a simple water filtration system using coffee cone/filter and granular activated carbon, (**Figure 3, bottom left**) all of which are inexpensive and commonly found in the home. During the activity, students were able to observe how a dye is removed from a colored water and asked to think about why carbons are effective to remove a contaminant by adsorption. The same coffee cone/filter was also used to make an ion exchanger to reduce water hardness. Although a commercial water softener using ion-exchange resins is often installed at homes supplied with hard water sources, I learned from the students that the concept of water softener and its underlying principles are largely misunderstood. Students were engaged in removing water hardness by pouring hard water to the coffee cone/filter filled with ion-exchange resin beads, of which efficacy was confirmed using hardness test strips until the water becomes soft (**Figure 3, bottom right**). Comprehensive explanations on commercial and industrial processes to reduce water hardness were given followed by the activity, which included a brief introduction to the state-of-the-art technology currently developed in PI Kim's lab.

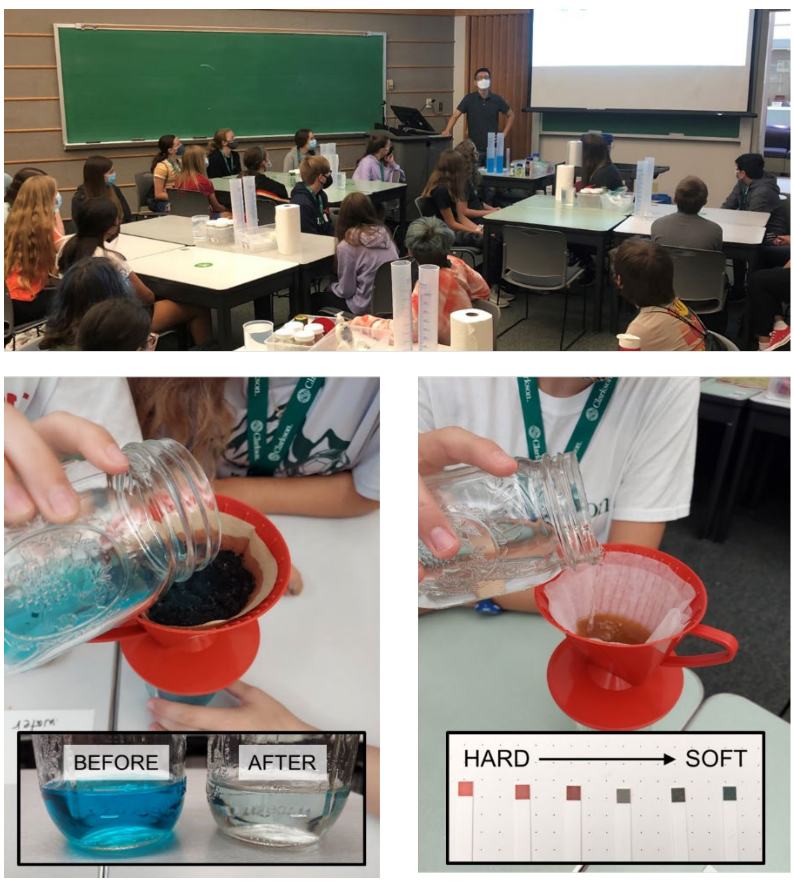

Figure 3. Photographs of the classroom at Clarkson University (top), coffee cone filter experiment with its result (bottom left), and water softener experiment with test strip results (bottom right).

2.3. North Country Children's Museum

A science program entitled "The Wonders of Water" was piloted at North Country Children's Museum located in Potsdam, NY, on December 11, 2021 (**Figure 4, left**). The goal of this pilot program was to conceptualize size-based membrane separation processes with hands-on experience, which was geared towards little kids of K-5 students or younger. In the first activity (**Figure 4, middle**), a sand sieve was used to separate water (sand) from salt (steel balls), representing membrane-based processes including reverse osmosis. In the second activity (**Figure 4, right**), the use of a magnet allowed for removing salt (steel balls) from water (sand), of which concept is similar to an electric-field-driven process using ion-exchange membranes. Approximately 20 kids and adults were engaged in these activities during 60-minute morning and afternoon sessions that were delivered by a science staff and a Clarkson's undergraduate students.

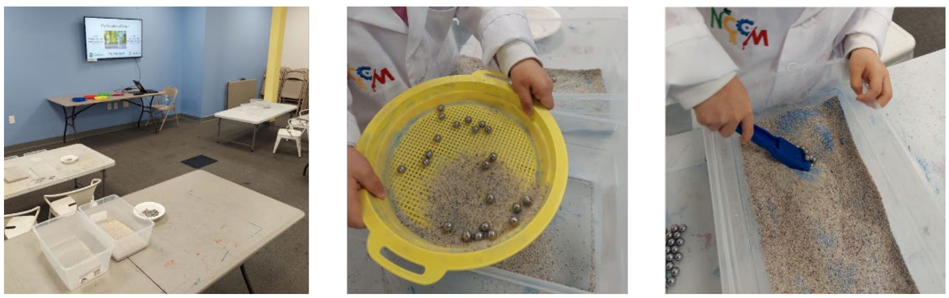

Figure 4. Photographs of the activity room at the North Country Children's museum (left), and activities using a sieve (middle) and a magnet (right).

3. Implications and future plans

Although the project was delayed due to the COVID-19 pandemic, we were rather able to engage students by connecting soap chemistry to coronavirus, explaining why washing hands help remove viruses. Electrochemical oxidation would also be an intriguing topic as a means to inactivating viruses. In addition to these, we introduced several water quality standards (e.g., salinity, hardness, and pH) and water treatment processes (e.g., filtration, adsorption, and ion exchange). The most common misconception we identified was about the freshwater distribution. The activity helped not only address the misconception, but also raise the awareness of the limited freshwater resources.

With the experience of piloting several modules in 2021, CU-BIRE will be able to provide enrichment opportunities for students in New York's greater Hudson Valley, including Beacon City school district and 8 other school districts with in-class, field trip, and summer programs. Beacon City school district has a majority of non-white learners, with 57% of students identifying as black/African American, Hispanic, or other minority ethnicity, and 45% of students are economically disadvantaged (NYSED data AY2018-19).

Acknowledgements

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