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A Summer Leader Experience for Rising High School Seniors – Integrating an Introduction to Environmental Science & Engineering

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Abstract

Each summer the United States Military Academy at West Point hosts approximately 1,110 rising high school seniors in a unique week-long immersive program called the West Point Summer Leader Experience (SLE). SLE students experience life at West Point, which includes exposure to academic majors, team-building athletic activities, and military training. Each participating academic department hosts several three-hour workshops during which groups of 20-25 students learn about an academic discipline in which they could major. Students are allowed to select workshops in academic departments from which they are most interested. The goal of the Department of Geography and Environmental Engineering is to provide students a better understanding of what it means to major in environmental science or environmental engineering. To support this goal, our faculty developed an exercise that uses a combination of lecture material and laboratory experimentation. During the 50-minute lecture period, faculty describe the attributes of both academic majors and introduce topics like water resources and quality, public health, fish biodiversity, and water treatment methods through interactive exercises. In the laboratory portion, students are divided into groups of 4-5 who then compete in a water treatment filter-building challenge. The students are provided with a water bottle, several different media (e.g., sand), a "challenge water," and water quality instrumentation such as turbidity, pH, and conductivity meters. Students are expected to design a filter, execute the design, develop a null hypothesis based on how the water quality will change, and run the experiment. At the end of the workshop, students are asked to complete a survey to determine the workshop's effectiveness. Anecdotal results from the 2023 SLE showed that students had little knowledge of the environmental science and environmental engineering professions prior to the three-hour workshop; however, students stated they had a fundamental understanding of each profession upon completing the workshop. Additionally, students found that the water treatment filter building challenge was generally a fun and useful approach to understanding what environmental engineers and scientists do in their professions. Results from this study suggest this type of hands-on workshop could be useful for high school major's fairs or other higher-learning institutions to help students understand different STEM professions and/or aid students in deciding an academic major.

1. High School Summer Workshops in the Literature

Summer workshops designed for high school students to learn about institutions of higher learning or specific academic disciplines are prevalent in the U.S. Studies evaluating the efficacy of such programs are also prevalent in published literature. For example, a query of ASEE's Peer Document Repository, which includes conference proceedings from ASEE conferences going back to 1996, for the key words "high school summer workshop" yields more than 3,350 results.[1] The same query specific to only the K-12 & Pre-College Engineering Division yields approximately 310 results. When results are limited to those incorporating environmental engineering, environmental science, and closely related disciplines, the number of ASEE publications is reduced to 22 results. The proceedings provide a variety of approaches to successfully execute a summer workshop centered on environmental engineering and science topic areas. Table 1 provides the authors, titles, and topic areas for a sampling of the most relevant articles from the ASEE Peer Document Repository.

Table 1. Sampling of High School Summer Workshop Studies. Table depicts the most relevant studies [A] identified through a query of the ASEE Peer Document Repository for environmental engineering, environmental science, and related disciplines or topic areas. Full citations are provided in the Reference section.

Author & Year	Title
Kurwadkar, et al. (2012)	Summer Merit Camp and Environmental Communication Week: Targeted Approaches to Environmental Engineering Education
Quintana-Cifuentes et al. (2019)	Sustainability Competencies in STEM Education at Secondary Schools: A Systemized Literature Review
Martinez Ortiz et al. (2015)	Engaging Students in Sustainability Education and Awareness of Green Engineering Design and Careers through a Pre-Engineering Program
Monaco et al. (2016)	Design of an Interactive Multidisciplinary Residential Summer Program for Recruitment of High School Females to Engineering.

[A] Each discrete inquiry provides a "relevance score" for an article based on the keywords used by the researcher. While a description of the relevance score is not provided on the ASEE website, studies with higher scores have more key words applicable to the query. Despite the usefulness of this search approach, some studies with high relevance scores have no bearing on the topic queried.

Querying the ASEE Peer Document Repository is not an exhaustive investigation of high school-level summer workshops; however, the number of ASEE publications in this genre does suggest its importance to pedagogical literature. Further, the limited number of studies directly applicable to educating and inspiring high school students about environmental topics simultaneously suggests there is space in literature for additional studies, such as the one presented in this work.

An evaluation of the literature beyond the ASEE Peer Document Repository provides further insight into high school STEM summer workshops, and points to the uniqueness of the workshop

[1] It is highly likely many of these studies do not directly address "high school summer workshops", but instead only contain one or more of those keywords. It is outside the scope of this study to conduct a thorough literature review of the ASEE Peer Repository.

presented in this study. Most notably, considering workshop length, most studies available in the literature are at least one day long, with many lasting multiple days or even weeks (Kitchen et al., 2018; Kittur et al., 2017; Roberts et al., 2018; Schmidt et al., 2020; Vallas et al., 2006; Yilmaz et al., 2010). Longer running STEM workshops can provide students with a variety of learning experiences over time to spark interest in various STEM disciplines. There remains, however, a notable gap in the literature concerning study of shorter workshops (i.e., those less than four hours in length) designed to accomplish similar objectives of more prevalent long-running STEM summer workshops. Accordingly, this study addresses the literature gap by describing a shorter workshop (less than half a day) designed to enhance high school students' interest in pursuing STEM disciplines in their post-secondary education. Specifically, the workshop discussed in this study was developed to enhance interest in the fields of environmental engineering and environmental science. The presentation of this hands-on workshop can be helpful to other institutions of higher education as they look to implement, or improve existing, summer experiences for prospective students.

2. Summer Leader Experience at the United States Military Academy

The Summer Leadership Experience (SLE) is hosted by the U.S. Military Academy to immerse rising high school seniors in a program designed to introduce the values, challenges, and opportunities specific to the university. Each summer approximately 1,110 students are selected to participate in SLE and travel to the institution for a week-long experience. The application evaluates students based on their academic resume that includes GPA, Scholastic Aptitude Test (SAT) or American College Testing (ACT) scores, their class rank, acceptance to the National Honor Society, participation in extracurricular activities, information on their physical condition, amongst others. During SLE, student participants engage in a dynamic combination of academic coursework, physical training, leadership development, and team building exercises (U.S. Military Academy, 2023). Through these hands-on activities, simulations, and interactions with other students and faculty, attendees gain insight into the leadership skills and teamwork required to uphold the institutions' core values of duty, honor, and country.

To help SLE students better understand the academic curriculum at the institution, academic departments provide a series of educational workshops. Each workshop is three-hours and hosts 20-25 students. The intent of the workshop is for students to learn more about academic disciplines in which they are most interested and could possibly major if they are accepted to the university. SLE students are not required to attend sessions from each academic department; instead, students are provided with a form listing available workshops and they rank order their choices. In total, each student attends three to four academic workshops during their SLE experience.

3. Summer Leader Experience Workshop Provided by the Environmental Program at the United States Military Academy

The Environmental Program at the U.S. Military Academy has three main goals for their SLE workshop: (1) to develop an understanding of what environmental science and environmental engineering study, (2) to provide insight into the activities of environmental scientists and environmental engineers in their profession, and (3) to spark intellectual interest in the field of study. To support these goals, our faculty developed an exercise that combines lecture material and interactive laboratory experimentation.

The 3-hour workshop is divided into two sessions. The first session is a 50-minute lecture period, which begins with the instructor providing a personal biography, an overview of the department, and available areas of study within the department (not exclusive of environmental engineering and science). Students are often asked to introduce themselves by providing their name, hometown, and why they would like to attend West Point. The lecture then narrows its focus, introducing academic majors within the environmental engineering and science program, discussing available courses and coursework, identifying indoor and outdoor laboratory experiences, and presenting research opportunities within the program.

The lecture period includes two activities designed to enhance student knowledge concerning water resource issues, such as water quantity, water quality, and the food-energy-water nexus. The first activity showcases how environmental scientists use fish surveys to research the ecological health of waterways. The instructor begins by providing background on how the presence/absence of different fish species can indicate the health of a waterway. Part of the introduction is a video clip from our university's aquatic science class, which shows faculty and students completing a fish survey using a 30-foot sine net. Students are also shown important fish identification characteristics, e.g., the shape of the dorsal fine and location of scales (Figure 1). Photos of fish collected during the sine are then shown to students so they can identify the fish's anatomy using physical characteristics and an online identification tool. Figure 1 provides an example. Students are asked to examine and identify physical characteristics of the fish in Figure 1. From there, each student uses Clearwater's Online Fish Key, which, if they label the characteristics correctly, will tell them that the pictured fish is a Striped Bass. Striped Bass are anadromous species that serve as "good" health indicators of the Hudson River, utilizing the estuary as a nursery ground. The second activity during the lecture session is an interactive discussion concerning how our university uniquely contributes to clean water and sanitation issues in developing countries.

After Session 1, students transition a lab setting for Session 2. The lab is intended to continue the conversation concerning water resources by focusing on water quality, accessibility, and public health. The first 15 minutes of the lab provides students with additional information describing the importance of drinking water treatment and various treatment methods, leading to a deeper discussion and presentation of lab-scale models on the role of filtration in the water treatment process. The discussion portion of the lab concludes with thoughts on how to design a filter to improve water quality (Figure 2) and a laboratory safety brief.

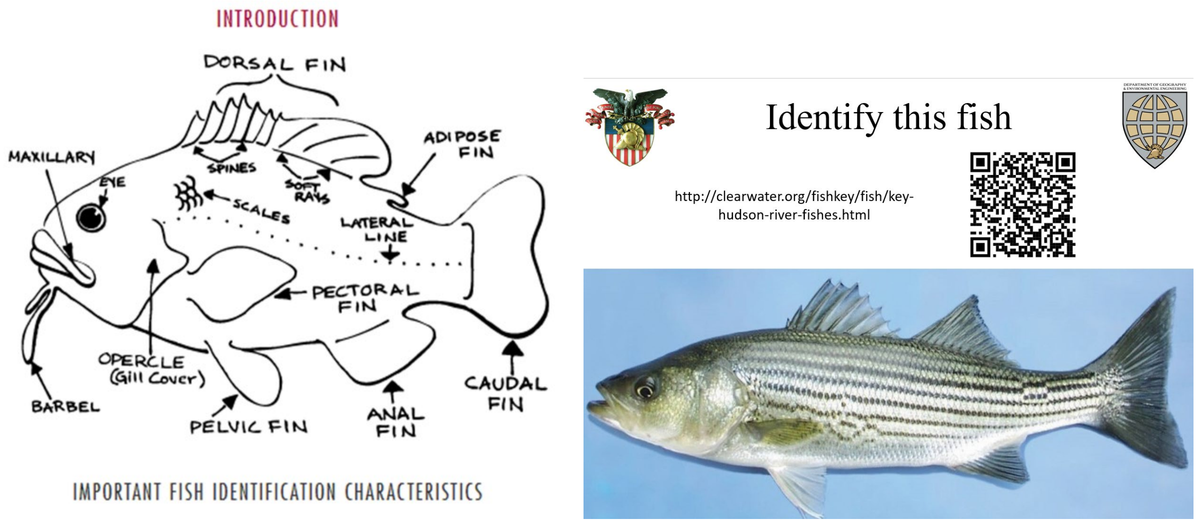


Figure 1. Students are provided with information on the key identification characteristics of fish (left) and asked to use a dichotomous key to identify the unknown fish species (right). Website URL and QR code for the Clearwater.org fish identification website are provided in the figure. The full website address is also found in the references.

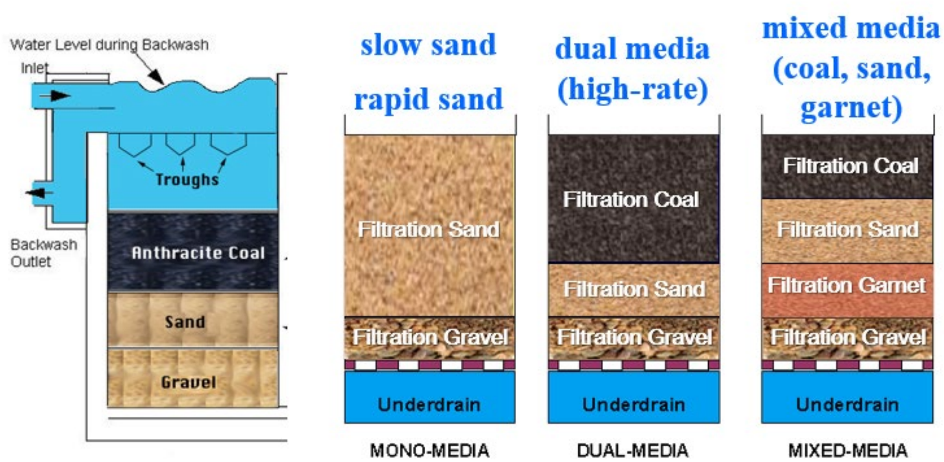
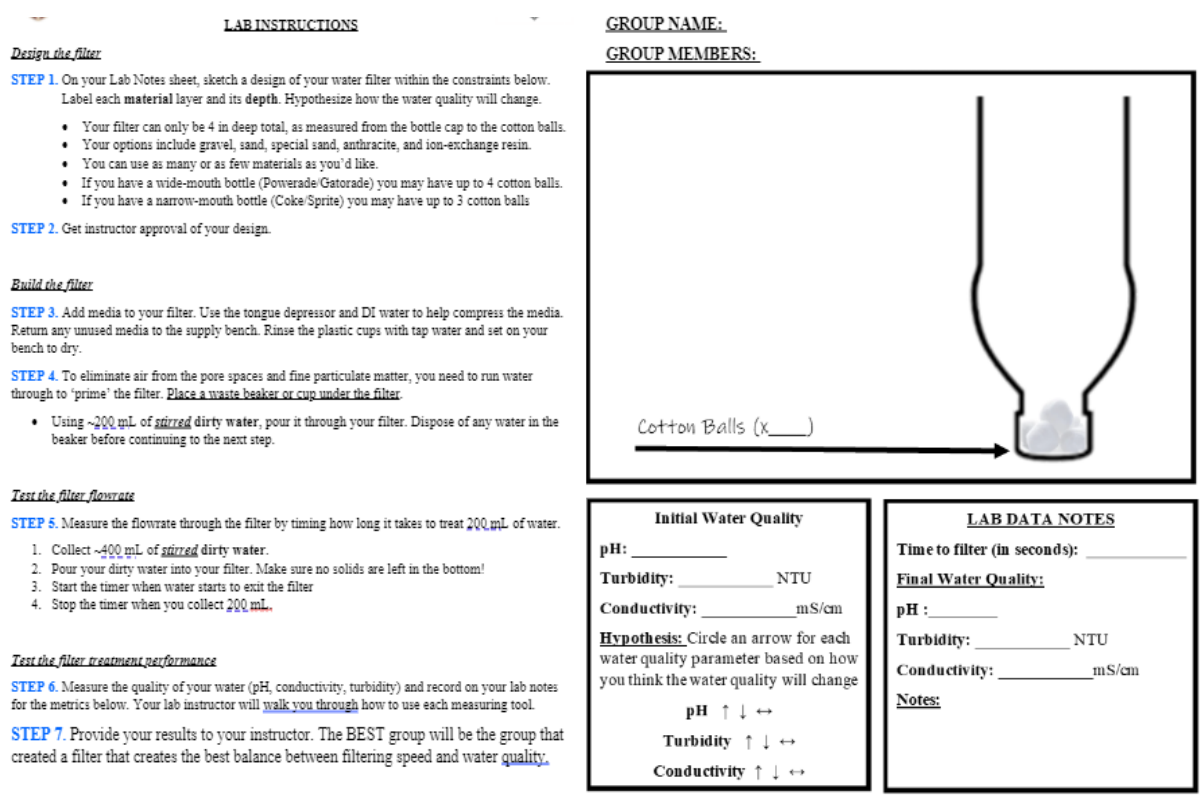


Figure 2. Slide is provided to students to show each the difference between filter types and media placement. Students are provided details such as how slow sand filtration are primarily a biological process, while rapid sand filtration is primarily a physical process. The discussion centered on filtration prepares students for the follow-on laboratory activity.

During the remaining ~100-minutes, students are divided into groups of 3 to 5 to complete an interactive water treatment filter-building laboratory challenge. Each group is provided with a laboratory instruction sheet (Figure 3), a water bottle, various media (e.g., sand, gravel, anthracite coal, or ion-exchange resin), a "challenge water," ruler, timer, and water quality instrumentation including turbidity, pH, and conductivity meters. Figure 4 shows the laboratory bench set-up, while Table 2 provides a list of equipment used in the laboratory. The "challenge water" is made in a 20-L carboy with 19-L tap water, 100-mL coffee grounds, 750-mL soil (clay-based soil is best), and 30-mL salt ($CaCO_3$). Students are expected to use the information provided during the lecture to design a filter, develop a hypothesis on how water quality parameters will be impacted by their specific design, execute the design, and run the experiment.



LAB INSTRUCTIONS

Design the filter

STEP 1. On your Lab Notes sheet, sketch a design of your water filter within the constraints below. Label each **material** layer and its **depth**. Hypothesize how the water quality will change.

- Your filter can only be 4 in deep total, as measured from the bottle cap to the cotton balls.
- Your options include gravel, sand, special sand, anthracite, and ion-exchange resin.
- You can use as many or as few materials as you'd like.
- If you have a wide-mouth bottle (Powerade/Gatorade) you may have up to 4 cotton balls.
- If you have a narrow-mouth bottle (Coke/Sprite) you may have up to 3 cotton balls

STEP 2. Get instructor approval of your design.

Build the filter

STEP 3. Add media to your filter. Use the tongue depressor and DI water to help compress the media. Return any unused media to the supply bench. Rinse the plastic cups with tap water and set on your bench to dry.

STEP 4. To eliminate air from the pore spaces and fine particulate matter, you need to run water through to 'prime' the filter. Place a waste beaker or cup under the filter.

- Using ~200 mL of *stirred* **dirty water**, pour it through your filter. Dispose of any water in the beaker before continuing to the next step.

Test the filter flowrate

STEP 5. Measure the flowrate through the filter by timing how long it takes to treat 200 mL of water.

1. Collect ~400 mL of *stirred* **dirty water**.
2. Pour your dirty water into your filter. Make sure no solids are left in the bottom!
3. Start the timer when water starts to exit the filter
4. Stop the timer when you collect 200 mL.

Test the filter treatment performance

STEP 6. Measure the quality of your water (pH, conductivity, turbidity) and record on your lab notes for the metrics below. Your lab instructor will walk you through how to use each measuring tool.

STEP 7. Provide your results to your instructor. The BEST group will be the group that created a filter that creates the best balance between filtering speed and water quality.

GROUP NAME:

GROUP MEMBERS:

Initial Water Quality

pH: __________

Turbidity: __________ NTU

Conductivity: __________ mS/cm

Hypothesis: Circle an arrow for each water quality parameter based on how you think the water quality will change

pH ↑ ↓ ↔

Turbidity ↑ ↓ ↔

Conductivity ↑ ↓ ↔

LAB DATA NOTES

Time to filter (in seconds): __________

Final Water Quality:

pH : ________

Turbidity: __________ NTU

Conductivity: __________ mS/cm

Notes:

Figure 3. Laboratory instruction sheet provided to each group. The left pane provides the seven steps students must follow to complete the exercise. The right pane provides the data sheet where students provide their filter sketch and record measured water quality parameters.

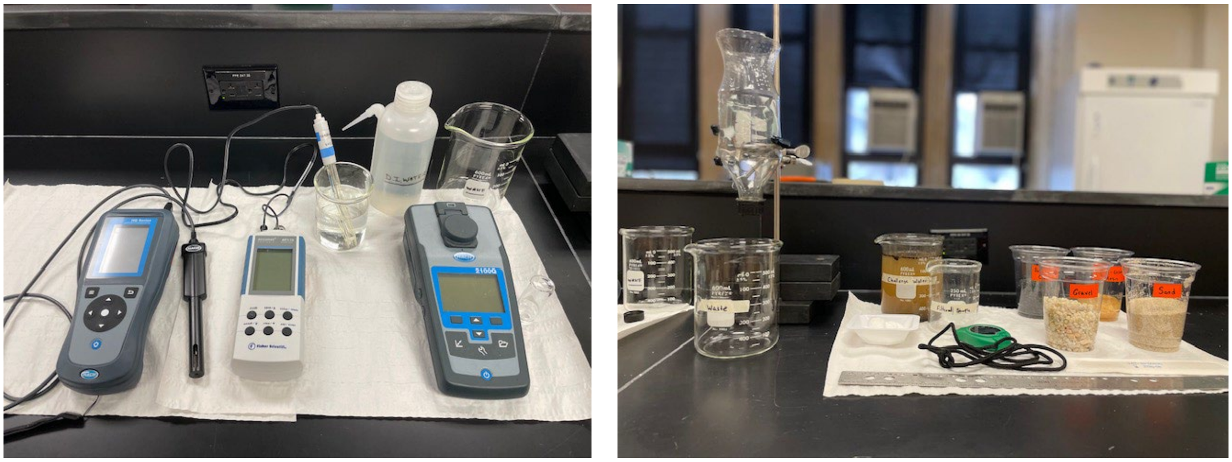


Figure 4. Laboratory set up for each of the five lab stations. Each group has between 3-5 students per work bench. The left pane shows each piece of equipment (see Table 2 for further description). The right panel shows the filter set-up and filter media used.

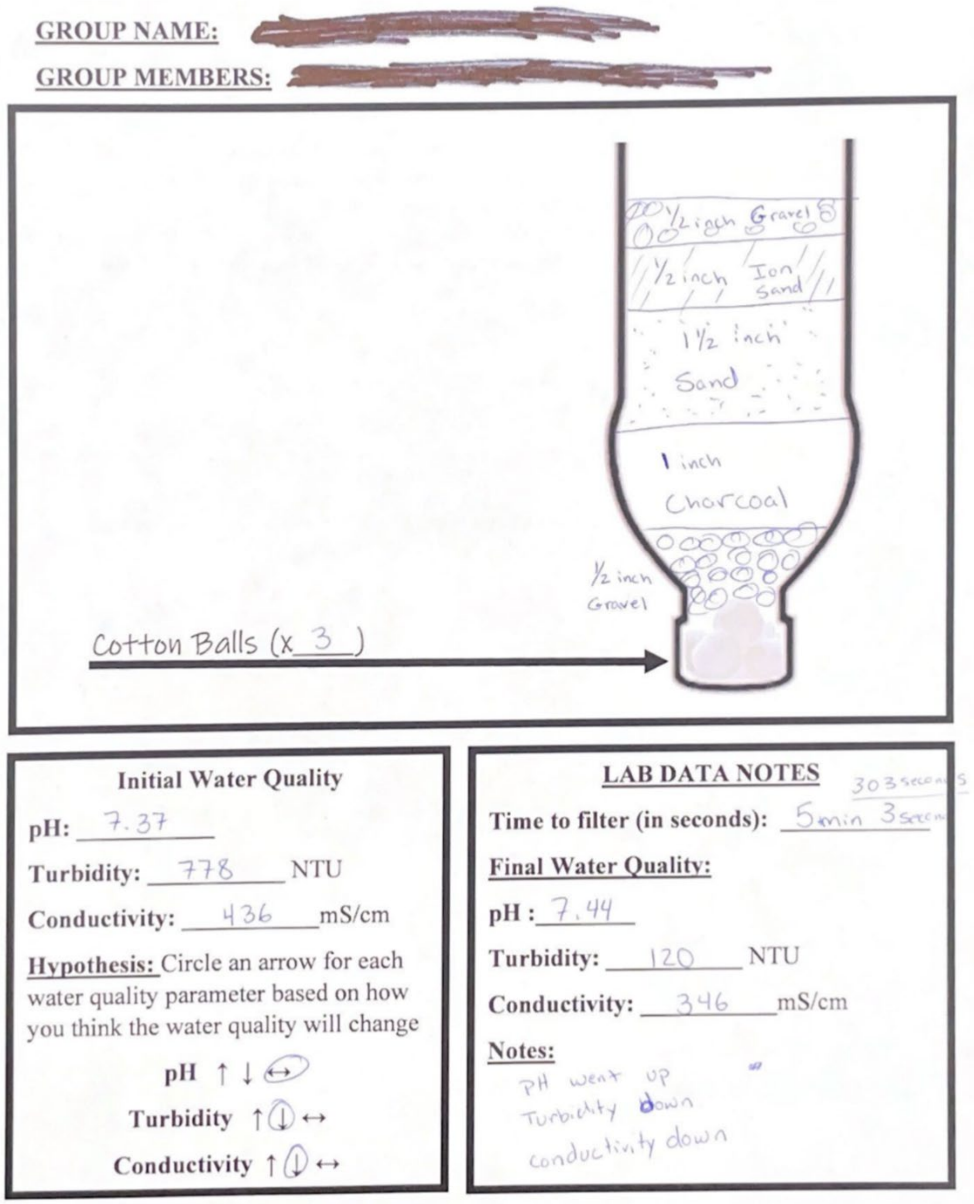
Table 2. Characteristics and specifications for laboratory equipment used for measuring water quality.

Equipment Name	Characteristics and Specifications
HACH® 2100Q Portable Turbidimeter	o Units: NTU o Accuracy: ± 2 of reading plus stray light (< 0.02 NTU) o Specifications: https://www.hach.com/p-2100q-portable-turbidimeters/2100Q01USB#specifications
HACH® HQ2200 Portable Multi-Meter with Conductivity Probe	o Units: mg/L or mS/cm o Accuracy: Conductivity ± 0.5% of reading: TDS ± 0.5% of reading o Meter Specifications: https://www.hach.com/p-hq-portable-meters-instrument-only/LEV015.53.2200A#specifications o Probe specifications: https://www.hach.com/p-intellical-conductivity-probes/CDC40101#specifications
Fisherbrand™ Accumet™ AP110 Portable pH Meter	o Calibrated using 3-point curve with > 90 EEF% o Specifications: https://www.fishersci.com/shop/products/fisher-scientific-accumet-ap110-portable-ph-meter-kit/13636AP110#?keyword=AP110

The only experimental design constraints provided to students are: (1) the filter can only be comprised of four inches of media and (2) each must have 3-4 cotton balls as a support base for the media. Teams have the freedom to use any combination of available media types, and layer them as thick as they choose within the water bottle. Prior to obtaining the filter media, teams must submit an engineer drawing (a basic sketch) of their design to the faculty member or lab technician. After the designs are approved, teams can begin construction of the water filters. Of note, all media is maintained in a centralized location to ensure it is not misused.

Students measure the initial water quality of the challenge water using the turbidity, pH, and conductivity meters. Once initial measurements are recorded, students prime each filter with 200-mL of challenge water to ensure that all media are saturated. Post priming, the students add an additional 400-mL of challenge water and record the time to treat 200-mL of challenge water to calculate the flowrate. The effluent is then tested for contaminant removal using water quality instrumentation to assess the filter's performance. The pH is also measured to determine any change. If time and resources permit students can modify their design and construct another iteration of the experiment. Figure 5a shows an example of a student's filter, and the corresponding student work can be found in Figure 5b. The instructor collects water quality data throughout the session and presents it to the entire class.

Figure 5a. Example of a student designed filter and the function of the filter.


GROUP NAME: [redacted]
GROUP MEMBERS: [redacted]

½ inch Gravel
½ inch Ion Sand
1½ inch Sand
1 inch Charcoal
½ inch Gravel
Cotton Balls (x 3)

Initial Water Quality

pH: 7.37
Turbidity: 778 NTU
Conductivity: 436 mS/cm
Hypothesis: Circle an arrow for each water quality parameter based on how you think the water quality will change
pH ↑ ↓ ↔
Turbidity ↑ ↓ ↔
Conductivity ↑ ↓ ↔

LAB DATA NOTES

Time to filter (in seconds): 5min 3seconds 303 seconds
Final Water Quality:
pH : 7.44
Turbidity: 120 NTU
Conductivity: 346 mS/cm
Notes:
pH went up
Turbidity down
conductivity down

Figure 5b. Example of student work.

At the end of the session, each student group is required to explain their filter design, report their results, and determine if their null hypothesis is valid. The instructor then reviews the performance of all filters and determines a "winning" group. The winning group receives a certificate of achievement for the best filter. Prior to leaving the lab, students are required to clean their equipment and arrange the bench to its previous condition.

4. Workshop Feedback and Path Forward

To evaluate this work, post-activity survey was given to all participants including Likert and free-response questions. Students voluntarily provided informal feedback concerning their interest in the fields of environmental science and engineering, their understanding of the professions, how well the workshop was received, and how to improve the workshop for the future (Table 3). Over three sessions, 57 students elected to provide feedback via survey.

Table 3. List of survey questions included in the voluntary survey. Students were asked to answer questions using a Likert Scale (1 to 5) with "5" being the highest score (e.g., "very interested"), "3" being neutral, and "1" being the lowest score (e.g., "very uninterested").

Survey Question	
Q1	How interested were you in learning more about environmental science and engineering when you signed-up for this workshop?
Q2	Going into the workshop, I understood what environmental scientists and environmental engineers do in their professions.
Q3	The classroom instruction portion of the workshop helped me understand the roles of environmental scientists and engineers (i.e., what they do for a living).
Q4	The fish identification exercise was a fun and useful approach to help me understand some of what environmental scientists do in their profession.
Q5	The filter for water treatment lab was a fun and useful approach to help me understand some of what environmental engineers do in their profession.
Q6	Leaving the workshop, I now have a fundamental understanding of what environmental scientists and engineers do within their profession.
Q7	Please provide thoughts on the workshop. If it is a positive, please put a "+" in front of your comment. If it is a negative, please put a "-" in front of your comment:

In general, both students and faculty believed the workshop was useful. More specifically, feedback suggested that most student participants were only mildly interested (Survey Q1, Score = 2.33 ± 0.82) and had little understanding of the environmental science and engineering disciplines (Survey Q2, Score = 2.72 ± 0.95) entering the workshop. However, leaving the workshop, the majority of participants reported having a fundamental understanding of what both disciplines do in their profession (Survey Q6, Score = 4.26 ± 0.64), representing a statistically significant improvement (t-Test, two-sample assuming unequal variances, $p \ll 0.001$). Further, students responded strongly to both lecture and laboratory components of the workshop. The classroom portion helped increase student understanding of both disciplines (Survey Q3, Score = 4.25 ± 0.47). Students stated that the fish identification exercise was generally a fun and useful approach to help them understand what environmental scientists do in their profession (Survey Q4, Score = 3.93 ± 0.93). Students also felt the filter for water treatment lab was a fun and useful approach to help them understand environmental engineering (Survey Q5, Score = 4.47 ± 0.82). Faculty indicated that the execution of the workshop provided a fantastic opportunity to work with younger students and introduce them to the disciplines. Faculty also indicated that the workshop did not take much time or energy to prepare for and execute.

These results suggest that many high school students do not understand the scope of responsibilities for those serving in the environmental science and/or environmental engineering disciplines. This is understandable, as most high school students are learning the fundamentals of chemistry, biology, physics, and earth science, and have learned much less about professions that synthesize each of these topics. The results also point to the importance of introducing disciplines like environmental science and engineering to high school students prior to their arrival to university – doing so can spark an interest that students had not previously identified. The workshop format presented here is a very straightforward approach to introducing high school students to environmental disciplines with little faculty overhead.

Anecdotal comments also helped illuminate areas that can be improved for future iterations of the workshop (Survey Q7; see Table 4, "Constructive Comments"). Some of the comments cannot be easily addressed due to laboratory space constraints (e.g., too large group sizes); however, modifications to Session 1 can be addressed. Specifically, faculty members will explore how to nest the fish exercise within a discussion of the entire Hudson River ecosystem, which is located next to our university's campus.

Table 4. Sampling of positive and negative anecdotal comments from student participants captured by faculty.

Positive Comments
Lab portion of the workshop allowed me to better understand the engineering process.
I enjoyed learning about a new profession that I hadn't really known much about and an interactive session really helped me gain an interest in Environmental Engineering.
Very engaging and team work inducing. It was a fun and interactive experience.
Love the independence the filter activity gave our teams. Allowed room for creative design in the experiment.

Constructive Comments
Lab was done with too big of groups. I get that it is unrealistic to ask for that with this many students but it would help individuals take more of an active role in the process.
Fish exercise didn't feel entirely relevant/thought out- possibly more emphasis on how the fish fit into the ecosystem/indicates about the ecosystem would be illustrative.
Classroom and lab felt slightly disconnected in lessons maybe more about filtration in class
Presentation was not as engaging towards end.

5. Conclusion

Workshops for high school students aspiring to attend college can be beneficial for many reasons, to include helping students understand which college to attend or which academic major is right for them. The U.S. Military Academy provides prospective students with both such opportunities through academic workshops at their Summer Leader Experience. This work provides environmental science and environmental engineering programs at other universities a template for a 3-hour workshop, which effectively presents both disciplines through several interactive sessions and hands-on exercises. Both the fish identification exercise and the filtration laboratory exercise can be easily replicated at other universities with little faculty overhead. Anecdotal student comments suggest that the workshop provides a strong introduction to two important academic disciplines that most were unfamiliar with prior to the experience.

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