Can online summer camps work? Evidence from adapting a high school hands-on water quality module for online delivery

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Abstract

There is evidence that participation in summer engineering camps facilitates students' understanding of the work engineers do, which can influence their decisions toward selecting engineering majors in college and engineering career paths [1]. The *Environmental Engineering and Sustainability* summer camp for high school students has been offered at the University of Illinois at Urbana-Champaign since 2012, under the summer camp outreach umbrella of the Grainger College of Engineering [2]. The week-long camp includes hands-on activities aimed to introduce students to engineering design, scientific inquiry, sustainability, and how engineers contribute to protecting human health and the environment. In summer 2020, due to the pandemic, the camp was reformatted from in-person to virtual. The virtual platform enabled the camp to reach more students, especially those with limited resources to attend an in-person camp. Therefore, we believe it is worth reflecting on the benefits and challenges of this reformatted summer camp and suggest ways online student experience can be improved in the future.

In this paper, we specifically focus on the water quality module, which was reformatted for online delivery. The module originally used multiple techniques (i.e., probes and test strips) to test the quality of various water sources, including a creek running through campus. The virtual module also tested water quality, but each student chose a water source near them and results were compiled and compared for different samples across the country. While both versions (in-person and virtual) included an interactive lesson on water quality and treatment, the virtual lesson was delivered to ten times as many students using video conferencing. The additional students and format had a unique set of challenges, but also enabled more student diversity and opportunities for discussion of water quality on a broader scale. This paper presents our observations of student engagement, student assessment, and formal feedback to evaluate the success of the virtual module and identify ways to improve this approach in future iterations.

1. Introduction

There is evidence that participation in summer engineering camps facilitates students' understanding of the work engineers do, which can influence their decisions toward selecting engineering majors in college and engineering career paths [1]. The *Environmental Engineering and Sustainability* summer camp for high school students has been offered at the University of Illinois at Urbana-Champaign since 2012, under the summer camp outreach umbrella of the Grainger College of Engineering (GCE) [2]. The week-long camp includes hands-on activities aimed to introduce students to engineering design, scientific inquiry, sustainability, and how engineers contribute to protecting human health and the environment. In summer 2020, due to the pandemic, the camp was abbreviated and reformatted from in-person to virtual, under the 'What It Takes' summer outreach activity of GCE. The virtual platform enabled the camp to reach more students, especially among those who could not afford to attend an in-person camp. However, it also created questions regarding its impact. Several studies have compared outcomes between face-to-face and online college student outcomes [3]. Summer STEM camps are designed for different age groups, have a short duration, and are designed with specific

learning objectives. Their overall purpose is to inform, motivate, and recruit students to STEM fields rather than to build expertise. There is a shortage of comprehensive studies regarding their impact and there is not much shared information about virtual camps, which were necessitated due to unusual social circumstances.

In this paper, we summarize a reformatted water quality module (WQM), reflect on the benefits and challenges of its reformatted virtual version, and suggest ways online student experience can be successful. In revisiting the WQM, for this paper, we focus on two aspects: student responsiveness and student and parent feedback.

2. Description of the module

In this section, we provide an overview of the original in-person module, describe modifications made for online delivery, and outline our efforts to improve participation between virtual camp sessions.

Original in-person module overview

The in-person camp was offered for 20 rising 10-12 grade students, per year. The original in-person WQM included approximately four hours of activities and instruction (Table 1). The module has been offered every year and its popularity has been consistently ranked high by the students. The module had the following learning objectives: (i) describe common water quality parameters and their accepted ranges for drinking, (ii) test water quality for different water sources, (iii) compare/contrast drinking water and wastewater treatment, and (iv) sketch a water or wastewater treatment plant design. To accomplish these objectives, the module was divided into two parts: water quality and water treatment. Within each part, there was a brief traditional PowerPoint lecture, discussion, and at least one hands-on activity. The water quality activity was a lab where the students measured water quality parameters for a variety of samples in the field and lab. The water treatment activities included short labs to demonstrate water treatment processes, a wastewater treatment plant tour, and a short treatment plant design project.

Table 1. Overview of in-person module activities, formats, and durations.

Activity	Format(s)	Duration
Water quality introduction	PowerPoint	0.5 h
Water quality lab	Hands-on activity	2 h
Water treatment introduction	PowerPoint, hands-on activity	0.5 h
Wastewater treatment plant tour	Tour	1 h
Water treatment plant design	Hands-on activity	1 h

The water quality portion of the module began with a short presentation to introduce the basics of water quality, how it is measured, and how it is regulated by different national and international agencies. Then students were divided into groups of four and completed the water quality lab. The water quality lab began in the field at a creek on campus, where students used test strips and probes to measure water quality parameters directly at the source. Then students returned to the lab to measure water quality parameters by the same methods for water samples previously collected from a campus water fountain, groundwater source, and mystery location. Groups assessed the quality of each water source to determine if it was safe to drink. Then they made a prediction about where they thought the mystery water was collected: an agricultural drainage ditch, a toilet, or a rainwater barrel.

The water treatment portion of the module similarly began with a short presentation to introduce the basics of water treatment, including typical water and wastewater treatment processes. While coagulation, flocculation, sedimentation, and disinfection were described, the students completed two short labs to demonstrate the processes. The first lab had students add alum to a water sample with high turbidity (muddy water) and watch as the particles coagulate, flocculate, and settle out, making the water clear. The second lab had students add bleach to tonic water under blacklight and watch the fluorescence disappear, demonstrating the disinfection processes. At the conclusion of the presentation and labs, we traveled to a nearby wastewater treatment plant, where an engineer guided students through the plant and described the processes used at their site. After the tour, we returned to the classroom where students worked in pairs to design and sketch their own water or wastewater treatment plant on poster boards (Figure 1).
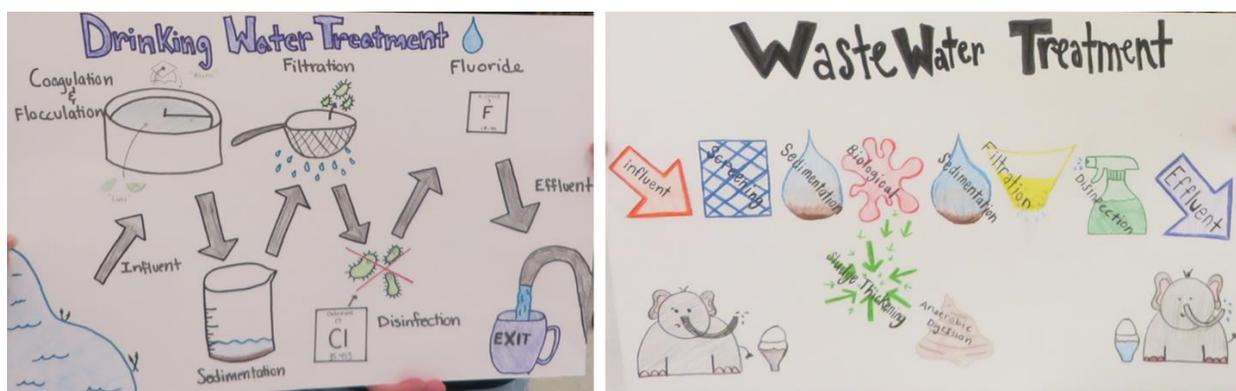
**Figure 1.** Sample student treatment plant designs from the in-person module.

Modifications for online delivery
A major difference from the in-person module was that the online platform allowed ten times as many students (of all genders) to participate, with 200 total students enrolled (divided into 100 for two separate camp sessions). The in-person WQM was modified to include a combination of at-home, self-paced activities (1.25 h) and synchronous activities (1.25 h) delivered via Zoom video conferencing platform (Table 2). While most of the learning objectives remained the same, objective (ii) was replaced with the following two objectives: describe how water quality is regulated in the United States and interpret and discuss water quality data. The module was still divided into two parts, with the water quality part predominantly completed independently by students and the water treatment part almost entirely synchronous.

Table 2. Overview of online module activities, formats, and durations

Activity	Format(s)	Duration
Water quality introduction	Video & PDF (at-home, self-paced)	0.25 h
	Zoom PowerPoint (synchronous)	0.25 h
Water quality lab	Hands-on activity (at-home, self-paced)	0.75 h
	Zoom break-out session (synchronous)	0.25 h
Water treatment introduction	Zoom session PowerPoint (synchronous)	0.25 h
Water treatment plant tour	Video (at-home, self-paced)	0.25 h
Water treatment plant design	Zoom break-out session (synchronous)	0.5 h

Since we had to provide individual lab kits for each student, we were unable to replicate the same water quality lab that included field probes and test strips for testing multiple water sources. Instead, we sent each student a complete set of test strips and instructions to test one water source of their choosing (e.g., tap, lake) (Figure 2). With bulk ordering, the kits cost $4.17 per student and were prepared individually by Test Assured [4]. In addition to the kit, students were sent a lab manual with instructions and discussion questions related to the lab. We also provided a video demonstration of the lab for students as an alternate at-home instruction style.
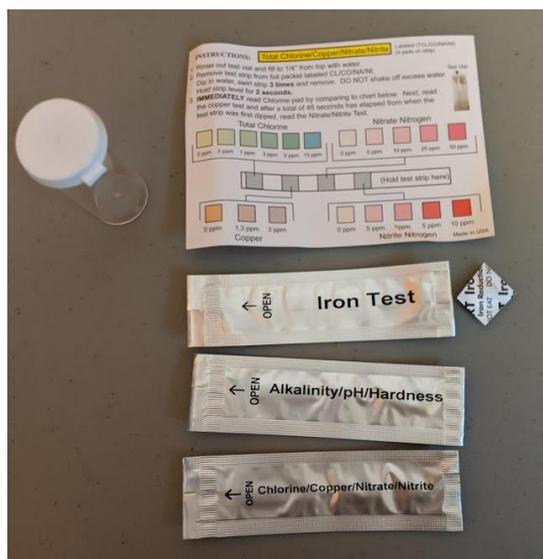
Figure 2. Contents of the lab kit sent to each student to test water quality at home. Included were instructions, sample vial, test strips, and iron tablet, all provided by Test Assured [4].

Using the provided kit, students tested the water sample for alkalinity, hardness, pH, iron, chlorine, copper, and nitrogen. Then we compiled data from each student about their water, including source, geographic location, and values for each water quality parameter tested. During the synchronous portion, we discussed the combined data set and reviewed figures that can be used to visualize the data (Figure 3). Then students entered break-out sessions (3-4 students/group) to discuss data for one parameter, form one or two conclusions, and select the figure that best illustrated their conclusion(s). After discussion in small groups, we rejoined as a large group and several students shared what they discussed with their partners. Since we did not have time to review every group's conclusions, students were encouraged to submit the assignment in the virtual classroom platform. We later reviewed all submissions and provided individual feedback for each.
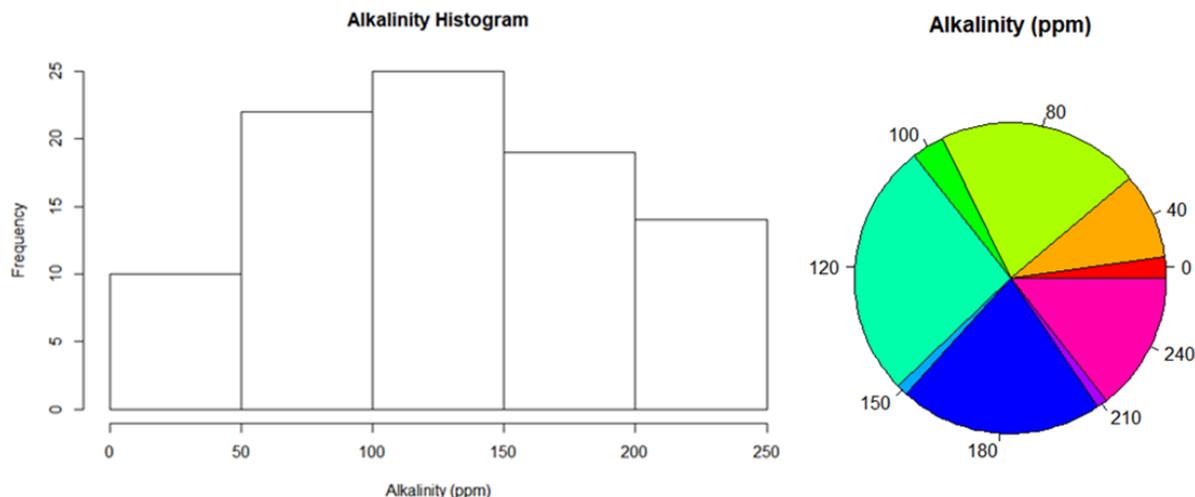
Figure 3. Sample figures (histogram and pie chart) created for each water quality parameter (alkalinity shown here) using the water quality data provided by the students from their at-home water quality lab.

The water treatment portion was almost entirely synchronous during the Zoom session. We used PowerPoint to introduce water and wastewater treatment and typical processes used in each. To replace the tour used in the in-person module, we provided an optional video tour of a water treatment plant for students to review at home. After the presentation, we split students into small groups of 2-3 and they met in break-out rooms to design a water or wastewater treatment plant. Since we did not provide materials (e.g., posters, markers) to complete the activity and students were distanced, we encouraged them to be creative in selecting a format to present their design. We reconvened to wrap-up the session, answer any questions, and provide information for how to submit their treatment plant designs in the virtual classroom platform. The students were polled to determine how much additional time they wanted to complete their designs and the deadline was selected by majority vote. Since we were unable to interact directly with students again after they completed their designs, we submitted individual feedback and grades for each submitted assignment through the virtual platform. Feedback focused on technical content (e.g., process flow) and creativity. In addition, we selected the four best designs from the entire camp and sent each of those students an award letter and small prize in the mail.

Improvement between online sessions
Since the camp had multiple sessions, we were able to improve our approach between sessions to increase student involvement. For example, we used social media platforms to boost involvement and excitement for the session. During the first session, we posted reminders in the camp group chat to complete the water quality lab and said how excited we were to explore the topic together in the deeper dive (synchronous session). During the second session, we built on this by addressing individual student questions (submitted with their water quality data) in the camp group chat. For example, one comment we posted in the group chat was as follows:
> *"For the water quality lab, some have expressed concern that they are not doing it correctly because they are getting mostly 0s. That does not mean you did anything wrong! In fact, considering many of you chose to do tap water or filtered tap water, these results are not unusual and are a sign of good, clean water. For most contaminants, we want them to have concentrations of 0 ppm or near 0. There are*

some exceptions, like chlorine, for which it is actually good to have some residual in your tap water to prevent bacterial and fungal growth in the distribution system (pipes to your home). But for those using a filter, this residual chlorine is most likely completely removed. Thanks for those who have entered results so far. Looking forward to getting more responses and looking at these data closer together next week!"

In addition to improving participation in the at-home activity, we worked to improve the number of assignments submitted. In the first session, we incentivized assignment submission by offering a prize to the two best designs. We also mentioned that we would provide feedback for each submission. For the second session, we similarly offered a prize, but we further emphasized that all assignments would receive individual feedback. We described some of the great submissions we received during the previous session and demonstrated the process for uploading assignments and reviewing feedback.

3. Outcomes
In this section, we summarize empirical observations and comments from an end-of-camp student and parent survey.

Participation and engagement
Nearly all students (94%) participated in some aspect of the online water quality module, with increased participation between the first and second sessions (Table 3). In particular, we observed increased student participation each time we responded to student questions in the camp group chat. More students completed the at-home lab, submitted their data, and volunteered comments and questions that showed they were thinking about water quality. The most common question asked by students was "where can we get more of these test strips?" showing that they were excited to independently explore this topic further. In addition, students showed initiative to investigate the topic deeper. They would write for example: "*I would like to run a test on the unfiltered tap water and see how effective the refrigerator filter really is, especially considering the filter is old by now*" and "*This was straight from tap indoors, but we recently installed a whole-house filter to keep the hardness down, which explains some of the results (the water in our area is very hard).*" Overall, 187 students across the United States submitted water quality data for their water sample (Figure 4 that we showed to students in the synchronous sessions).

Table 3. Participation in 2020 online summer camp by session.

Session	Total students	Completed at-home lab	Signed up for deeper-dive	Submitted deeper-dive assignments
1	100	89	45	19
2	100	98	52	33
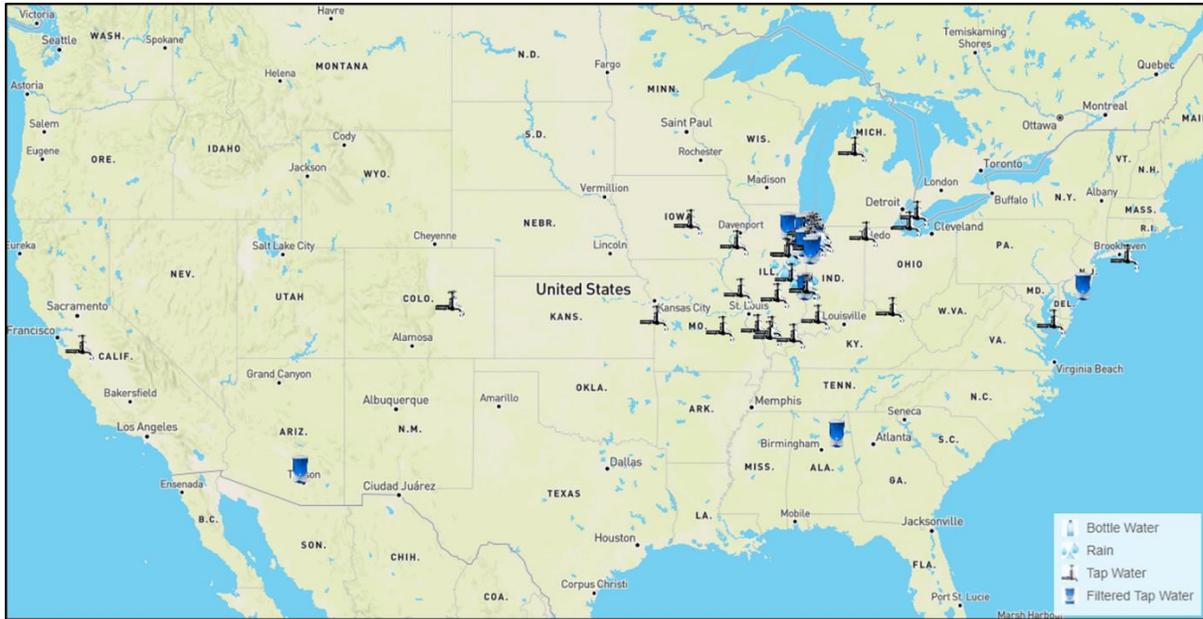
Figure 4. Map showing locations where water quality data were submitted for samples from bottled, tap, filtered tap, and rainwater sources.

While all students in the in-person session completed the treatment plant design activity, students in the online module had lower overall participation. Some of this is likely from difficulties in working virtually in small groups to complete the activity. However, we had some creative submissions using a variety of formats (example in Figure 5). In addition, submissions increased between sessions, which we attribute to how we further emphasized that individual feedback would be received for their submissions.
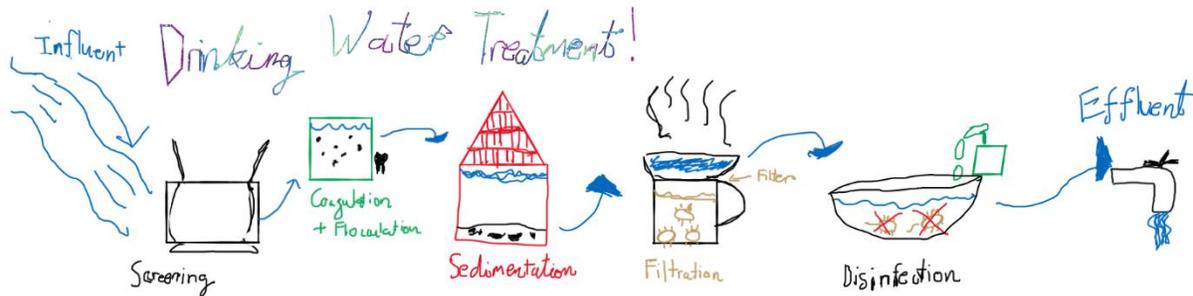
Figure 5. Sample student treatment plant design from the virtual module.

Survey results
Students and parents were invited to complete a survey at the end of the camp. The results are not specific to the WQM but to the whole group of Civil and Environmental Engineering modules. Therefore, here we summarize feedback that corresponds to the virtual aspect of the camp overall, and how students and parents felt about it. A total of 106 students from the first group of students completed the survey and 36 from the second group. Overall 52 parents also responded.

At the end of week 1, among 104 responding students, close to 100% said they were 'much more interested" (49%) or 'interested' (48%) in Engineering. Overall 100% of responders said they enjoyed the camp and they would do it again, if there was no in-person option and many said that they would do it again, even with an in-person option available. 97% said they would recommend the camp to others. Sample camper comment:

> *"This camp has taught me the importance of thinking outside the box, collaboration, and determination. I truly felt like a quintessential engineer, and the staff did a great job of implementing this in the camp. For these reasons, I would recommend this camp to anyone who is looking to explore engineering."*

An important aspect of the in-person camp is building of social connections, especially lasting ones. 29% of the online campers said they definitely built such connections and 43% that they somewhat built such connections during the virtual camp, which we find to be very encouraging.

Summarizing student preferences and suggestions, students let us know the following:
- Approximately 80% of campers noted that the hands-on activities were a favorite part of camp. They emphasized that their favorite modules were the ones where they had to build things or do things other than constantly watching a screen.
- Many campers wished for more clear instructions inside the kits, with students who persisted and eventually completed the labs indicating a more positive camp experience overall.
- Campers liked content describing the different branches of engineering and how a given module related to the bigger picture.
- Some campers noted that they enjoyed working independently and that needing to work with a partner for at-home activities was not practical or even feasible.
- Campers indicated preference for use of simple technology that was easily accessible, even with old and slower computers.
- Campers appreciated communication and access to the instructors during the asynchronous periods.

Parent feedback was overall positive, with parents expressing gratitude for the effort it took to make the camp happen and indicating the camp had shifted their students' interest toward engineering and applying to the host University. The biggest complaint came from parents who said they were not technology savvy and they had to spend huge amounts of time to help their students prepare their computer environment to be able to run the activities.

4. Conclusion

In this paper, we first described how we reformatted a water quality module for online delivery. A major benefit of this virtual format was that we were able to reach ten times as many students. However, this format also made student engagement more complicated. We ended by summarizing student and parent comments regarding their overall experience with the virtual realization of a summer camp. These comments were consistent with our own perceptions that inspired us to improve the module for the second week of camp to further increase participation. The main improvement made between sessions was increasing the frequency of communication with the campers to keep their interest and motivation high. Campers responded every time we probed them with a question or comment and when they knew they will obtain feedback. Overall, we learned that human interaction is key for the success. In our experience, consistent student-instructor interaction was critical for keeping the student engaged. For a short duration camp, it is harder to build student-student interactions, although that can be facilitated with platforms that

enable teamwork. Finally, availability and familiarity with technology should be taken into account, with choice of widely available software and provision of detailed instructions of using it to cover for environments where technology is not widely used, yet. This will further support access by students from all socioeconomic and cultural backgrounds.

Acknowledgments

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