3D Printed Drinking Water Treatment Facility for Engineers at Liberal Arts College

Juliet Johnson, Hampshire College

Dr. Juliet Johnston (she/they) is a new assistant professor at Hampshire College. While technically an environmental engineer, their primary focus is on leveraging microbial communities for biodegradation and bioremediation. She teaches courses on environmental engineering, environmental microbiology, and bioinformatics. She previously was a postdoctoral researcher at the Georgia Institute of Technology focusing on the transcriptomic responses of nitrifying bacteria in wastewater. Before Georgia Tech, they were a postdoctoral researcher at Lawrence Livermore National Laboratory with Dr. Mayali using microbial encapsulation techniques to explore how microbial communities behave in aggregates. Johnston has previously taught as a part-time lecturer at the University of California Berkeley and as an adjunct professor at the University of St. Thomas. Outside of the lab, she can often be spotted lounging in coffee shops, DIY crafting, or out on hikes with her husky, Ava.

3D Printed Drinking Water Treatment Facility for Engineers at Liberal Arts College

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Tags: STEAM, environmental engineering, drinking water, 3D printing

Abstract

"I want to safely drink 1-cup of water before the end of the semester" was the main objective given to students who were told to build a semi-functional drinking water treatment plant. The remaining goals of this project-based learning style were up to students to develop the 3D printable drinking water treatment plant and the accompanying lesson plans. This relatively simple project idea was the throughline for my entry-level Environmental Engineering course taught to students at a small private liberal arts college. As the only engineering course offered at our private liberal arts college, my mission was to connect engineering themes and concepts to students who originally had little interest in the topic.

STEAM education is often de-emphasized at smaller private liberal arts colleges where students are used to engaging in social justice work, community education and advocacy, as well as artistic expression. Students often enroll in these college programs explicitly to deemphasize difficult math and engineering skill sets in favor of humanities and arts courses. To better engage with the students at a small private liberal arts college, I proposed students design a small-scale, 3D printable drinking water treatment facility and develop lessons plans for future educators. This project-based learning style helped students engage with the difficult math subjects and the open-access educational aspect promoted a sense of purpose in otherwise rote work. By making "develop open-source materials and accompanying lesson plans" a central mission of our project, students were able to engage with passion knowing their work had significance for other educators. This project was not just a small one-off assignment, but the start a larger community engagement activity and could be continually used as demonstrations outside classroom settings.

While this course serves as more of a general engineering course at our institution, the emphasis on environmental engineering offered a more focused approach to an array of topics. Furthermore, this course is the only strict engineering course at our institution but is now serving as a gateway for students to take similar engineering courses at nearby partnered institutions. While there are some topics which were de-emphasized to create space for such a large project-based learning environment, ultimately students showed an increased interest and more confidence with practical math, engineering, and science communication skills by the end of the course.

Introduction

Hampshire College is a small private liberal arts college where there is no dedicated engineering program. Every student graduate with a bachelor's degree in arts, and each student gets to craft their own major. While typical engineering courses are not traditionally offered, there is still a demand for students to learn how to build and craft things. Hampshire College has rigorous mathematics courses and a Center for Design which functions as a Makerspace with 3D printers, electronics work, metal work, fiber crafting, and glass blowing. Our students thrive in building and designing things with few courses providing direction. Additionally, our students have a passionate love for the environment and being responsible stewards for the land. Students frequently work on our campuses farm, food forest, greenhouses, and appreciate our living buildings. There is a hunger to build something that benefits the environment, so I created a specially crafted project-based course for Environmental Engineering Principles.

Students were tasked with creating a semi-functional drinking water treatment plant designed for 3D printing, along with accompanying lesson plans aimed at future educators. The primary goal was to help me safely drink one cup of water by the end of the semester. A seemingly simple objective that became the catalyst for deeper engagement with engineering principles. As the only engineering course offered at the college, this class aimed to connect engineering with students who were often more interested in the humanities, social justice, and the arts. The project was designed to bridge this gap, making complex engineering topics more accessible and relevant. The mathematical principles and general concepts were equivalent to a freshman-level general engineering course, while the content remained higher at a junior level environmental engineering course.

Methods

Overview

Students were given several classes on drinking water treatment, and several labs to reinforce key topics before embarking on an open-ended project to build a drinking water treatment plant. On the final day of class, students connected their treatment plant components together to test out their designs. Afterward, students were given an evaluation survey to assess their thoughts and feelings surrounding the project and the effectiveness of their designs.

Preparatory laboratory classes

Lab #1 Hydraulic Retention Time: Students were given various supplies: a graduated cylinder, stopwatch, plastic bottle, aquarium pump, water, calipers, a ruler, and a sharpie. They were asked to find a suitable height on the bottle for a small exit hole to be drilled. This hole must suit a hydraulic residence time in the plastic bottle for 2-minutes, 5-minutes, and 10-minutes. Students would need to calibrate the pump and measure the volume of water across the timescales.

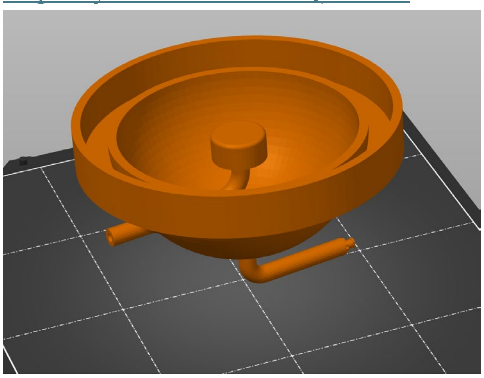
Lab #2 Coagulation and Flocculation: Students were given a stock of aluminum sulfate at 5 g/L, 50mL of dirty water from the nearby river, a turbidimeter, a shaker table, and pipettes. Students were asked to randomly guess the concentration of alum to dose their water between 0 mg/L and

100 mg/L as samples were shaken slowly for 20-minutes and settled for 20-minutes before measuring final turbidity.

Lab #3 Filtration Lab: Students were given sand, gravel, perlite, and granular activated carbon as potential media. They were tasked with removing methylene blue, measured by UV-spectrophotometer in cuvettes. Falcon tubes were given with holes drilled on the bottom so that "unfiltered" water could be dropped by pipette on top and collected below.

Lab #4 Water Quality Sampling (at UMass): Students went to the University of Massachusetts Amherst to sample the campus pond. Four sites on the pond had water collected for turbidity, pH, conductivity, nitrate/nitrite, phosphorous content, and fecal contamination.

Lab #5 Fusion 360 CAD for Sedimentation Basin: Students used Fusion 360 and were led by a guest instructor Benjamin Cowden to build a sedimentation basin featuring luer lock connectors.
https://youtu.be/E91lMQY24ck



Lab #6 Operational Demo with Water Bottle Drinking Water Treatment Plant: A small-scale drinking water treatment plant was built and designed by Dr. Juliet Johnston to demonstrate how all the systems worked together.

Lab #7 Tour of the Amherst Water Treatment Plant: We went on a field trip to the local drinking water treatment plant to obverse their basin designs and measure their water quality.

3D Printing and Fabrication

Most 3D printing was performed using the Bambu P1S with basic matte PLA filament. Students were given an overview of the machine and were allowed to make up to 3 50%-scaled prototypes. Additionally, students were encouraged to go to nearby makerspaces such as the Hampshire College Center for Design and the UMass Makerspace for printing and assembling outside of class. Students were also supplied several plexiglass boards measuring 5'x7' and 8'x10' to increase visibility into their basin designs. Tubing, small cheap aquarium pumps, magnetic stir bars and stir plates were provided to help the design process. Katadyn Micropur purification tablets were provided as an alternative disinfectant.

Deliverables

The final deliverables expected from students included their final design for their treatment plant process, an accompanying lesson plan to showcase any part of the drinking water treatment process, and the final evaluation survey.

Evaluation

A final survey was given to all 16 students at the end of the class to reflect on the project. The questionnaire had 4 sections: Overall reflections, the designing aspect, the lesson plan, and any additional comments. The questionnaire is provided in the supplemental materials below. Please note that a final rubric or grade was not assigned to this project since Hampshire College does not provide letter grades. Instead, students are given a written evaluation emphasizing their efforts and areas for improvement.

Results and Discussion

Deliverables and Participation

There was a total of 5 groups and only 3 of these groups successfully turned in a final design to be printed and tested in our class's final project. Only 6 of the 16 students turned in a final lesson plan. 12 of the 16 students completed the final evaluation. All 12 students who completed the final evaluation filled out aspects for the overall project and the design aspect but only 9 responded to the lesson plan section. Of the designs submitted, two groups designed sedimentation basins, and one group designed a filtration basin. An accomplished student also designed mixing tanks for coagulant to be added and disinfection. One of the sedimentation basins had significant design flaws and was not able to be tested. **Figure 1** highlights the final design where textbooks were used to improvise the hydraulic gradient moving downstream.

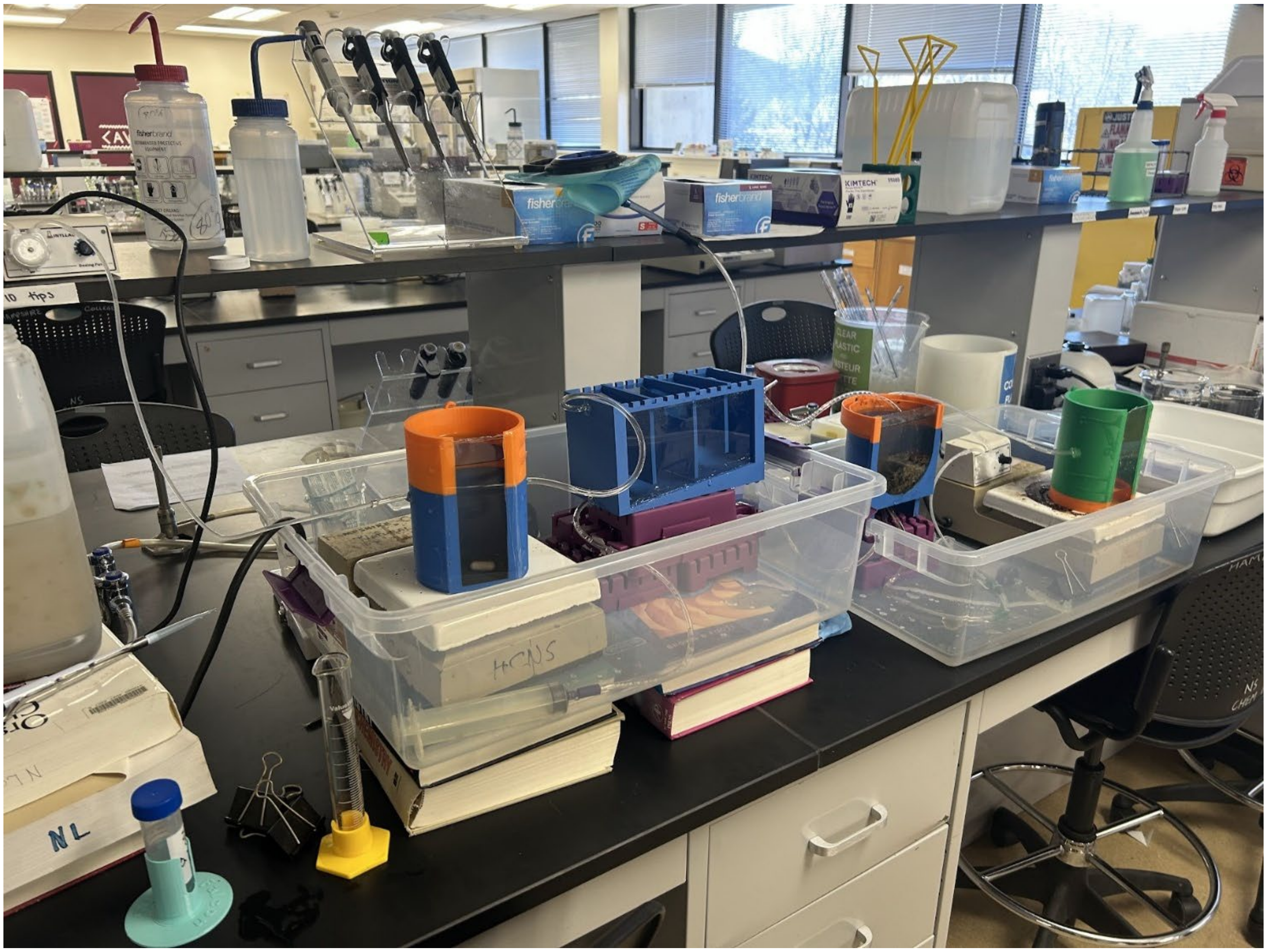


Figure 1 Photo of the assembled drinking water treatment plant where untreated water (leftmost bottle, moving to the right) is pumped into the coagulant dosing basin before entering the sedimentation basin. The filtration basin was filled with sand a granular activated carbon before a final dosing basin for disinfection.

The deliverables (or lack thereof) highlight one of the greatest challenges this project faced, which was student attendance, and willingness to work on projects outside of class. Numerous students faced significant personal struggles and lack of motivation to attend class regularly and on time. This left many groups with scattered goals and unorganized responsibilities. This project also requires students to spend a significant amount of time outside of class designing and building their own components. Very few students showed initiative to accomplish work in a timely manner outside of class which caused significant frustrations across teams.

While regular attendance of class was not tracked, many students were consistently late or had numerous unexplained absences. This impacted groupwork significantly where hard-working students left remarks on their survey stating: "I hate that people didn't show up to class because I feel that it hindered a lot of the things you wanted to show us…"

Student Response to Project Based Learning

One of the evaluation questions asked, "In comparison to other courses, did you enjoy this deeper dive into one big topic with a project, or would you have preferred a broader course covering more topics in environmental engineering?" Student responses were mostly affirming the love for a deeper dive of the course with 9 positive responses, 2 neutral, and one student who expected a broader course. Several of the positive responses indicated they wished that the course was a 2-part course to allow more time for other broader course topics (such as wastewater, landfilling, and recycling) while still providing ample time for a deeper project into drinking water treatment facilities.

Additionally, students were asked to rank if they felt this was a meaningful assignment and whether this assignment helped them *feel* like real environmental engineers as shown in **Figure 2**. Overwhelmingly, students found this assignment to be meaningful with an average of 8.73 ± 1.53. Responses for whether they felt like an engineer or not were significantly lower (Students T-Test $p=0.002$) with overall feeling like an engineer average of 7.25 ± 2.09. Students who reported "not feeling like an engineer" coincide as the same students who were not routinely attending class and struggled to maintain roles during groupwork.

While not everyone felt as affirmed as an environmental engineer, most students were able to articulate real-world design problems they faced and how their team overcame these problems. For example, one group working on filtration systems needed a way to create backwash and developed a water bladder system which could be squeezed to provide pressure. Another team benefitted from trying multiple sedimentation basin designs before finalizing on a system that met their criteria. These are examples of prototyping and design which are critical real-world skills for engineers. Broader classroom assignments usually have one answer and one solution for engineering students to solve for, whereas this type of project-based learning lets them truly feel like engineers.

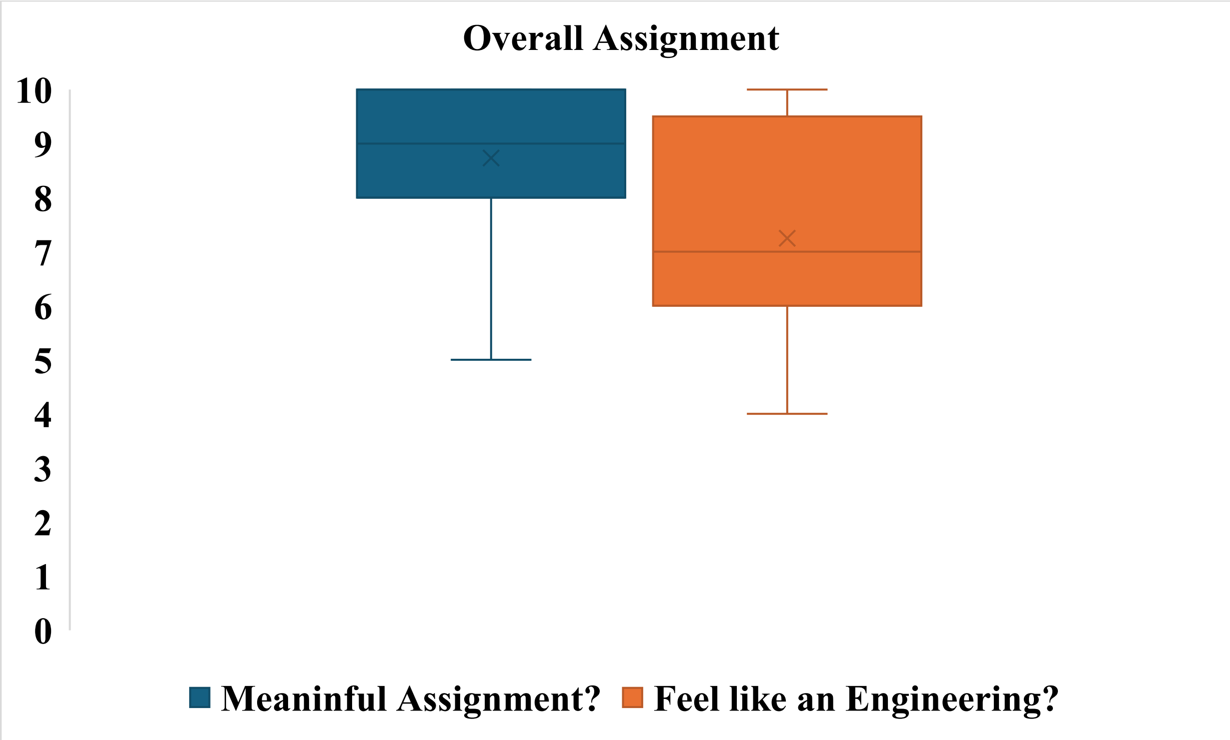


Figure 2 Students were asked "On a scale of 1-10, was [this drinking water treatment plant] project a meaningful assignment?" and "On a scale of 1-10 do you feel like you got to be an environmental engineer while building, designing, and iterating on this project?" 12 students reposed to both questions with an overall meaningful assignment average of 8.73±1.53 and an overall feeling like an engineer average of 7.25±2.09.

Design and Iterating

Evaluations asked students several questions specifically about the design process and if building physical models helped them conceptualize the theoretical information. The quantitative responses on a scale of 1-10 asked if they had fun designing, did they learn about designing and iterating, and if they felt accomplished. Students had a lot of fun (8.08±1.38), and learned a lot (8.46±1.08) but didn't feel as accomplished with their work (7.5±1.58) as shown in **Figure 3**. Most of their written responses attributed this to unsuccessful designs or the feeling that they needed to have contributed more to their teams' efforts. There were overwhelming positive written responses that project based learning helped students appl and conceptualize theoretical knowledge. Statements included "It helped me learn how to adapt and work to optimize a design based on the limitations we had (specific dimensions of tubing, limited materials and resources etc.)." and "It absolutely helped me feel like I understand what is actually happening at a water treatment plant."

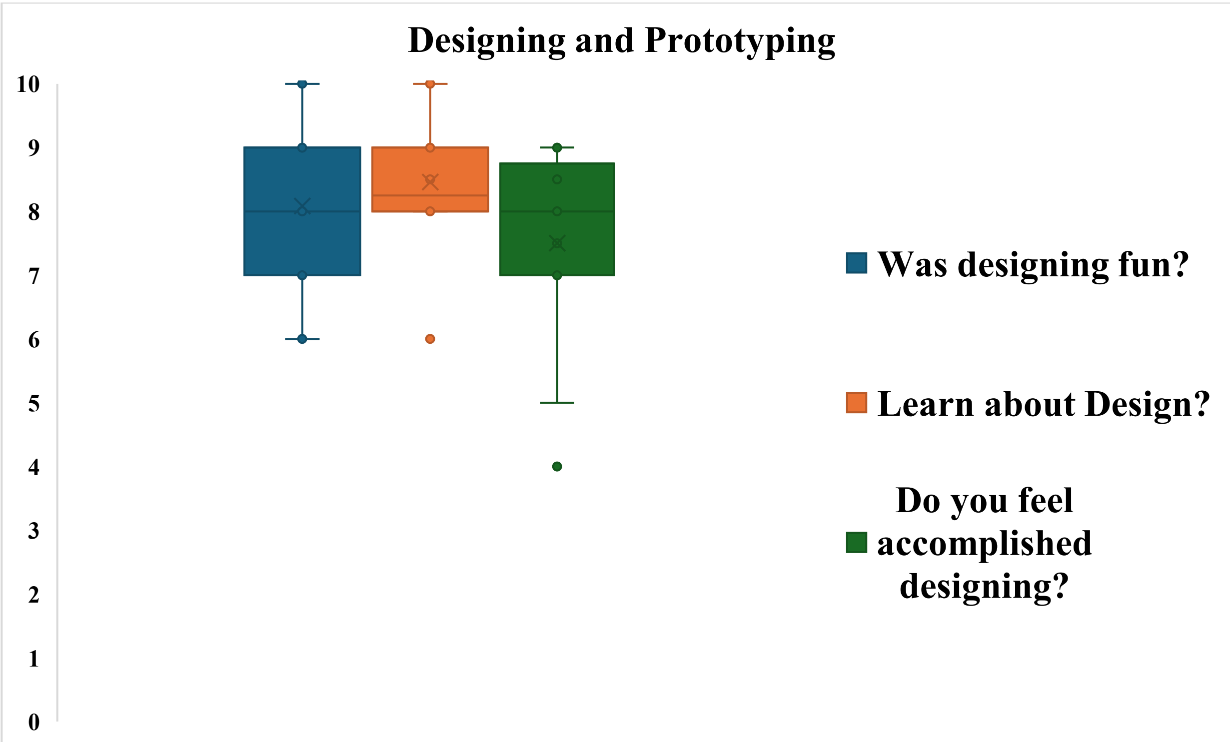


Figure 3 Students were asked three questions on a scale of 1-10 which included: "Did you have fun designing?" "Did you learn about design and iterating?" and "Do you feel accomplished?" Each average was respectively Fun: 8.08±1.38, Learning: 8.46±1.08, and Accomplished 7.5±1.58. Most of the class, 12 out of 16 students responded to these questions.

Student Lesson Plans

The goal of the lesson plan assignment was to help students develop their own curriculum based around their 3D printed drinking water treatment plant. Only 9 students responded to the survey regarding their lesson plans and only 6 students turned in a final lesson plan. When answering questions on a scale of 1-10 (**Figure 4)**, students overwhelming felt that the lesson plans were fun (8.33±1.58), helped deepen their understanding of the topic (7.83±1.66), and felt satisfied with their work (8.17±1.27).

Several students claim they forgot about this aspect of the assignment, or believed it was not their role in the group (despite their name not being listed on the 'groups' lesson plan). While some students excelled and replied, "teaching somebody is the best way to learn that thing" and "yes, outlining the structure and agenda helped me better understand the fundamentals of water filtration and the mathematics behind it…" For the students who did turn in their lesson plans, it appears to be a valuable assignment, but stronger conclusions cannot be made without greater participation.

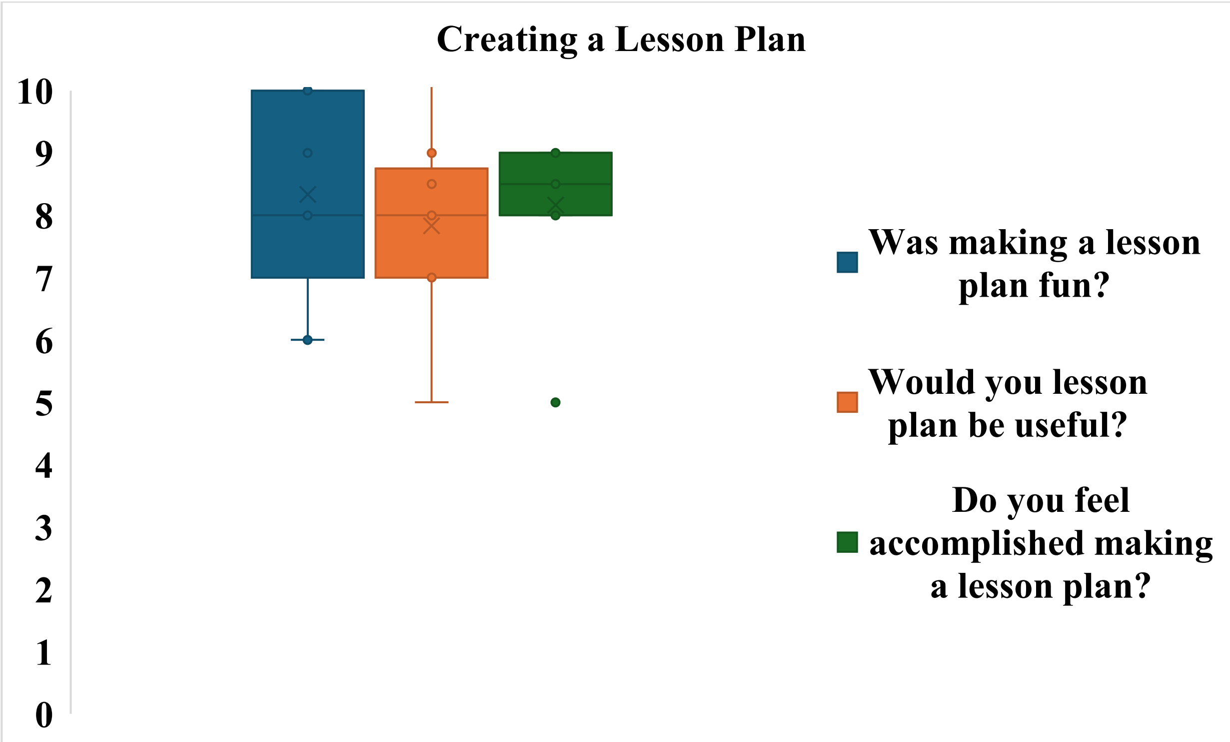


Figure 4 Students were asked three questions on a scale of 1-10 which included: "Did you have fun developing a lesson plan?" "If you could go back in time, do you think your lesson plan would've helped you learn more about the material??" and "How satisfied are you with you lesson plan?" Each average was respectively Fun: 8.33±1.58, Learning: 7.83±1.66, and Satisfied 8.17±1.27. Only nine students responded to these questions since many students did not submit a final lesson plan.

Conclusions

Designing and building a 3D printable drinking water treatment plant was a highly successful opportunity for first year and out-of-major students to get hands-experiences designing and building. Students left this course feeling invigorated that they could become engineers and have increased confidence in their math and STEM capabilities. This project helped students apply theoretical knowledge and truly conceptualize processes. The major challenges were lowering the other content of the course to make time to emphasize drinking water treatment plants (i.e. wastewater, landfills, recycling), and student participation. Fall 2024 presented significant political and personal struggles for students, which lowered participation across all courses. When students fell behind on this group project, they struggled to find their place back on the team and reintegrate after several absences. This left many students feeling less accomplished since their final design was unsuccessful or not ready. Additionally, some of the open-ended aspects of this assignment were too challenging for students to foresee early during the design process resulting in many last-minute design challenges (i.e. tubing connections and hydraulic gradient). Most of the challenges faced are things which can be tweaked and improved in future versions of the course, which was ultimately a successful and fulfilling experience for most students.

Name ______________________

Lab #1 Hydraulic Retention Time

Part 1

Create a reactor that can use a single outlet hole and can reliably switch between an HRT of 10 minutes, 20 minutes, and 30 minutes. Dr. Johnston will drill an outlet hole at your desired height (you get one chance!).

Then, you must mathematically prove your system works and demonstrate the 10-minute HRT.

Please show all your work and turn this assignment in at the end of class.

You have 45 minutes.

Your time starts now.

Name ______________________

Lab #3 Hydraulic Retention Time

Part 2

Plan the conversion of your system into a PFR using the tubing provided. How long would does the tubing need to be for an HRT of 5 minutes, and 10 minutes?

Please show all your work and turn this assignment in at the end of class.

You have until the end of class.
Your time starts now!

Lab #2: Coagulation and Flocculation

As a class, find the optimal dose of Alum (Aluminum Sulfate) to remove as much sand, organic matter, and particles from the Hadley Reservoir.

The person with the closest to optimal dose of Alum wins.

Your time starts now.

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1) Write down your guess on the board
   a. My guess is ________ mg/L (between 0 – 100 mg/L)
2) Weigh your 50mL water sample before pipetting
   a. Weight of falcon tube + water _____________ g
3) Calculate an appropriate volume to pipette and add the dose
   a. I am adding _______ µL of _________ mg/L Stock
4) Weigh you water sample after pipetting
   a. Weight of falcon tube + water + alum ___________ g
5) Mix samples for 10 minutes
6) Let sediment settle (30 minutes)
7) Measure pH using a pH strip
   a. My pH is _________________
8) Remove supernatant water into a scintillation vial and measure Turbidity
   a. My turbidity is __________________ FTU
9) Weigh you water sample after pipetting
   a. Weight of falcon tube + water + alum ___________ g

Name ________________________

Lab #3 Filtration Lab

Part 1

Caution! We are working with methylene blue. This is a toxic dye which can stain clothes and irritate skin. Please wear gloves, long pants, and closed toed shoes.

Simulate a CSTR and a PFR to remove methylene blue using your given filtration media. Plot the effectiveness of your filtration media at removing methylene blue from solution.

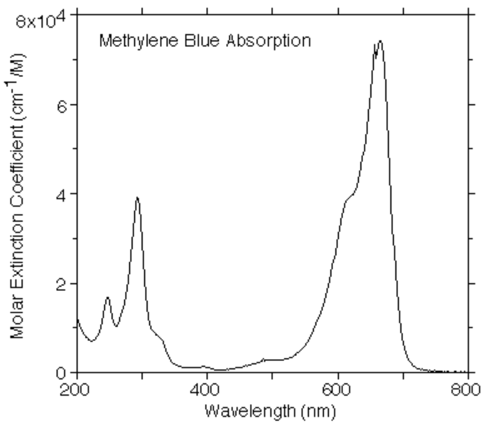
Sand	Gravel + Sand	GAC	Perlite
Team 1	Team 2	Team 3	Team 4

You have 45-minutes

Your time starts now.

Name ________________________

Use cuvettes on the spectrophotometer to measure "absorbance" of methylene blue at ~668nm wavelength.



<u>Controls</u>

Blank (pure water absorbance) __________

100% contaminated water _______________

Cotton Swab Absorbance _______________

Weight of Tube + Cotton _______________g

For each experiment: run 15-mL of methylene blue solution.

PFR: Try to capture the "tail" end of you 15-mL.

CSTR: lightly shake your "reactor" for 2-minutes. Use a cotton swab to help keep filtration media in tube when pouring into cuvette.

	3 mL or ____ g	6 mL or ____ g	9 mL or ____ g	12 mL or ____ g	15 mL or ____ g
CSTR					
PFR					

Extra challenge: Slowly keep adding methylene blue to the 6-mL PFR system and continuously track the effluent. Find the filters "breakthrough" point where it becomes significantly less effective.

Total Volume									
PFR									

LAB #5: Water Quality Analysis for the Tan Brook Watershed

DUE DATE: April 17/18 2024 (7 days from the day of lab) MEMO ONLY

OBJECTIVE

To analyze the quality of water in the Tan Brook watershed near or on the UMass campus and make recommendations for further studies or attention.

INTRODUCTION

The Tan Brook Watershed is an urban stream system that is heavily impacted by its surrounding area. The Brook is sometimes underground (pipeline stream, **Figure 1**) and others daylighted as it travels behind the Amherst-Pelham Regional High school, through Amherst Center, to the Campus Pond, and on to the west of the UMass Amherst Campus to an eventual outflow of the Mill River.

Please read the description and tour of the Brook, and a study of its water quality here:

- von Hausen, N., Smith, R., 2014. Qualitative and Comparative Analysis of Stormwater management in the Tan Brook Watershed. https://scholarworks.umass.edu/tanbrook_research/2/
- Clay, M., Smith, R., 2014. The Environmental Condition of Tan Brook and Campus Pond, A Community and University Concern (Research). https://scholarworks.umass.edu/tanbrook_research/3

From this latest available information on the Tan Brook Watershed (from 2014): ("Tan Brook Project | University of Massachusetts Amherst Research | ScholarWorks@UMass Amherst," 2014):

- 3,190,839 square meters or 1.232 square miles
- 45.5% of the watershed is covered in an impervious surface (asphalt or concrete)
- 83% of the watershed is developed
- 73% of the stream is piped underground
- Of the buried sections, 68.73% of the land within 200 ft is developed.

The objective of this lab is to collect and analyze data to support or negate a case to invest further resources in studying the water quality in and sources of pollution to the Tan Brook watershed.

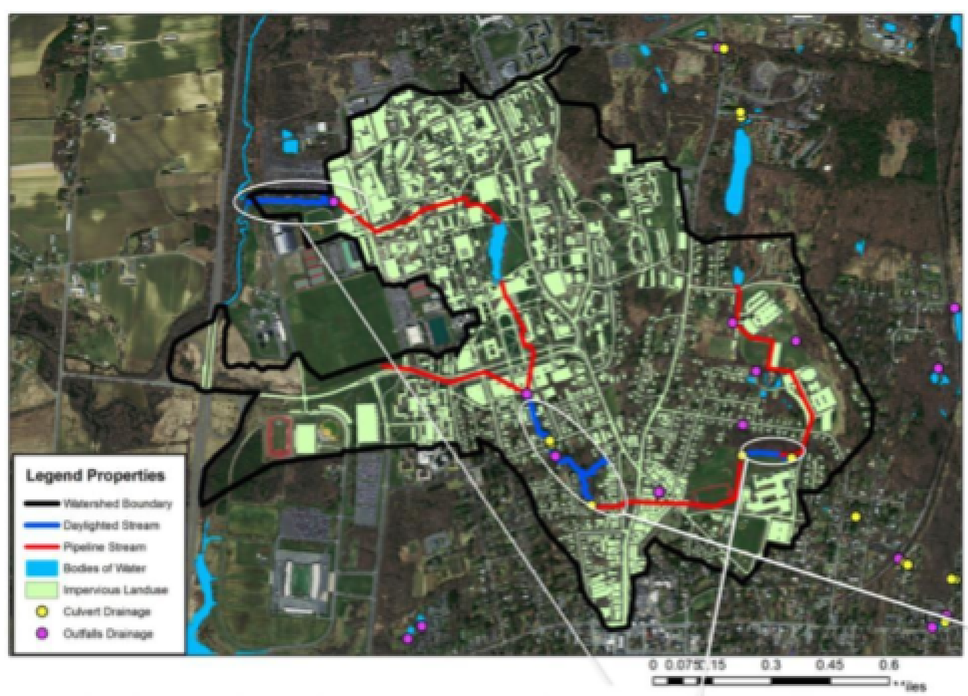


Figure 1. Tan Brook watershed (von Hausen and Smith, 2014).

OVERALL PROCEDURE

1. The students will take samples and determine water quality from the following parameters:
   a. On-site parameters
      i. Dissolved Oxygen
      ii. pH
      iii. Temperature
      iv. Specific Conductivity
      v. Turbidity
   b. In-lab parameters
      i. Orthophosphate
      ii. Nitrate
      iii. Total Hardness
      iv. Total Coliform & E. *coli*. (demo)
2. Teams will use the equipment and analyze samples. Each team will take measurements at their location for each of the above parameters.
3. Take photos and observations of the location. This includes (1) one "upstream", (2) one "downstream", (3) one "across the water surface", (4) and one "looking downward at the shore".
4. Enter your data into a class Google Sheet.
5. Analyze the entire class's lab data (statistical analysis)
6. Memo (one per group).

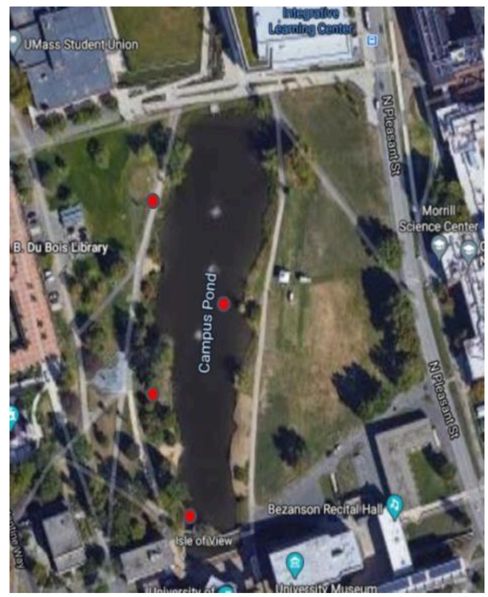


Figure 2. Birds eye view of sampling locations

SAMPLING LOCATIONS

- The sample locations are shown in the opposite photo.
- Samples should be collected to contain primarily water (try to avoid scooping up any sediments)
- It would also be helpful to record the location of where you collected the sample (you can get the GPS coordinates from your phone's map application) for later display (you can use Google Maps to collect them, or an app such as this).

MATERIALS

- Field notepad/pencil/pen
- Marker/Masking tape for labeling
- Gloves
- Antiseptic wipes
- 4-6 sample containers or beakers (>=500 mL)
- DI water (for rinsing vials and bottles)
- Coffee filters (for sediments)
- Thermo Scientific Orion Star A223 Dissolved Oxygen Portable Meter Kit
- 2 Hach DR 900 Portable Spectrophotometers
- Sample vials
- Kim wipes
- Orthophosphate reagents
- Waste containers
- Nitrate color viewing test kit
- Total Hardness test kit
- IDEXX test kit

PROCEDURES

Dissolved oxygen (DO) and Temperature

DO and temperature will be measured using the Thermo Scientific Orion Star A223 Dissolved Oxygen Portable Meter Kit (manual is here). Temperature and dissolved oxygen must be measured **immediately** (ideally in-situ, which means by putting the probe directly into the pond); samples could be collected for pH and conductivity and measured after collection.

Conductivity and pH

Conductivity and pH will be measured using *in situ* probes.

Turbidity

Turbidity will be measured using the Hach DR900 and the following procedure (https://www.hach.com/asset-get.download-en.jsa?id=17292739401). Units will be given in Formazin Nephelometric Units (FAU); however, many of the documentation you will find when researching turbidity for your report give units of Nephelometric Turbidity Unit (NTU). For our purposes, **1 FAU= 1 NTU**

Nitrate

Nitrate will be measured using the Hach Low Range Nitrate Test Kit (0-1 mg/L)
https://cdn.bfldr.com/7FYZVWYB/at/jx6xr58bnftfxczh87j4thq/DOC3269800027_Nitrogen__Nitrate_Test_Kit_Manual__Model_NI11__Color_Disc_Kit_146803pdf.pdf

Orthophosphate

Orthophosphate will be measured using the Phosphorus, Reactive (Orthophosphate) Powder Pillows method (procedure here: https://www.hach.com/asset-get.download-en.jsa?id=7639983836, pages 1-3).

Total Hardness: Calcium and Magnesium

Total Hardness: will be measured using the Drop Count titration method (procedure here: https://images.hach.com/asset-get.download.jsa?code=387564)

Total Coliform and *E. coli*

Total Coliform and E. *coli*: will be measured using the IDEXX Colilert test (procedure here: https://www.idexx.com/en/water/water-products-services/colilert/)

WRITE UP: PROFESSIONAL MEMO

In 2024, funds were available through the Massachusetts Department of Environmental Protection for watershed protection groups. Prepare a Memo to UMass Facilities that describes the results of your water quality an analysis and describes whether or not there is a need to do a thorough watershed assessment and more water quality analyses to identify how to improve the Tan Brook and Campus Pond water quality.

Memos are used frequently in professional engineering settings as an informal report that is clear and concise. This memo should be written to as a "Field or Lab Report", that summarizes the work you did. The expected sections will include: 1) purpose; 2) methods; 3) results; 4) discussion of the results; and 5) suggested next actions.

One 3-4 page memo per group addressed to UMass Facilities with data from all the lab groups. It should include the following:

Title:

A relevant and original title for your memo.

Purpose:

- Describe the purpose of the lab and the Tan Brook Watershed
- Show a map of the sampling locations.

Methods:

In your own words, briefly describe the methods you used, including the sample locations you selected, number of samples, and methods and equipment for analysis you used. (ie. Turbidity was measured using a Hach DR900. These should be brief and **do not** include each step such as wiping down vials etc.)

Results:

- Include photos of the sampled locations and observations of the pond/brook and nearby area
- Using the entire lab day's dataset, calculate a table with the mean values ± standard deviations for all analyzed parameters.

Discussion:

- Describe each water quality parameter you measured, what it represents, and why it is important.
- Discuss the significance of the values measured.
- Compare your data to the previous sampling effort in 2014 (look at values for common parameters in graphs from (Clay and Smith, 2014)) and the values for dissolved oxygen, temperature, nitrogen, and phosphorus in Lake Warner from the State Of The Lake Report 2019 Lake Warner Hadley, Massachusetts (posted on Canvas); Lake Warner is downstream of the Campus Pond).

Next Actions:

- State what should happen next (either a recommendation or suggested action).
- What else would you want to test for that you did not?
- Describe whether or not there is a need to do follow-up studies to identify how to improve the Tan Brook and Campus Pond.

Author Contribution Statement:

- List the specific contributions of each group member. For example: Data collection (EK, LD, BL), methods (LD), results tables (EK), discussion (BL), next actions (EK, LD, BL). While different students may focus on preparing different sections of the memo, all students should review the full memo.

References:

References should be listed here, if used.

REFERENCES

Clay, M., Smith, R., 2014. The Environmental Condition of Tan Brook and Campus Pond, A Community and University Concern (Research). https://scholarworks.umass.edu/tanbrook_research/2/.

Tan Brook Project | University of Massachusetts Amherst Research | ScholarWorks@UMass Amherst [WWW Document], 2014. URL https://scholarworks.umass.edu/tanbrook/ (accessed 9.7.20).

von Hausen, N., Smith, R., 2014. Qualitative and Comparative Analysis of Stormwater management in the Tan Brook Watershed (Report). https://scholarworks.umass.edu/tanbrook_research/2

The below table is not all encompassing of all data that should be included in the report

		ON-SITE PARAMETER					IN-LAB PARAMETERS			
Team Members	**Sample** #	**Temp.** (^{0}C)	**DO** (mg/L)	**pH**	**Conducti v ity** (uS)	**Turbidity** (FTU/ NUT)	**Ortho-Phosphate** (mg/L)	**Nitrate** (mg/L)	**Total Hardnes s** (mg/L)	**Calcium Hardness** (mg/L)
	1									
	2									
	3									
	4									

Grading Rubric:

Category	Criteria	Points	Comments
Purpose	Is the purpose of the lab well-described? Map of sampling locations shown?	/5	
Methods	Were the methods clearly defined, including locations, number of samples, methods, and equipment?	/15	
Results	Were there photos and descriptions of sampling locations and observations? Were results presented clearly in a table? Were calculations accurate?	/25	
Discussion	Is each water quality measured described with its meaning and importance? Is the significance of the measured values explained and interpreted? Was there a comparison with the other values and interpretation of what that meant (from 2014 and Lake Warner in 2019)?	/25	
Next Actions	Are other ideas for sampling and testing described? Is the need or lack of need for follow-up studies necessary?	/15	
Overall Presentation	Was the overall memo logically organized and coherent? Were sources clearly cited?	/15	
Total		**/100**	

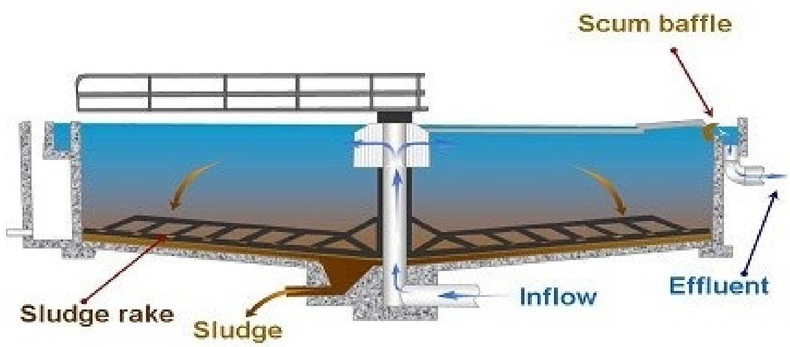
Lab #5 Sedimentation Basin in CAD

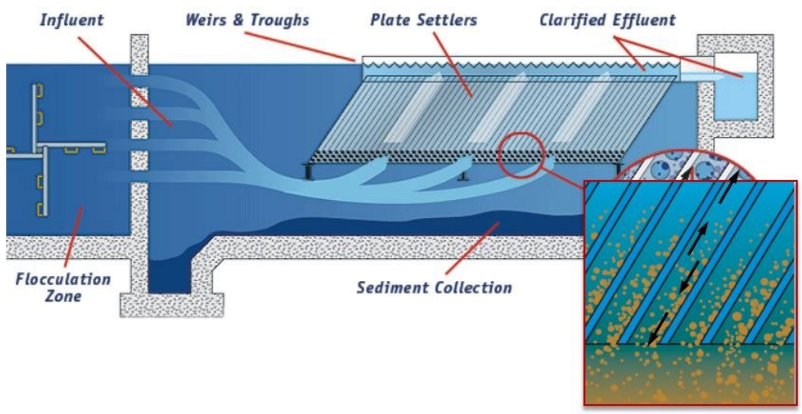
Build a sedimentation basin using FUSION 360.

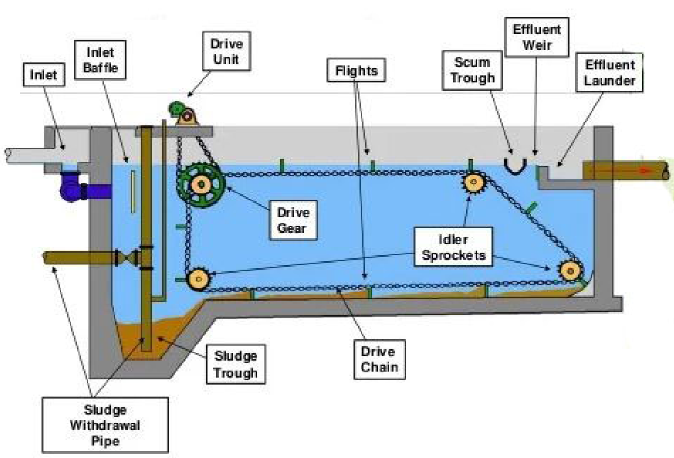
Afterwards, reflect on how you might change your basin design, or make adjustments suitable for educational demonstrations and 3D printing.

You have until the end of class.

Your time starts now.







Lab #6 Drinking Water Treatment Plant

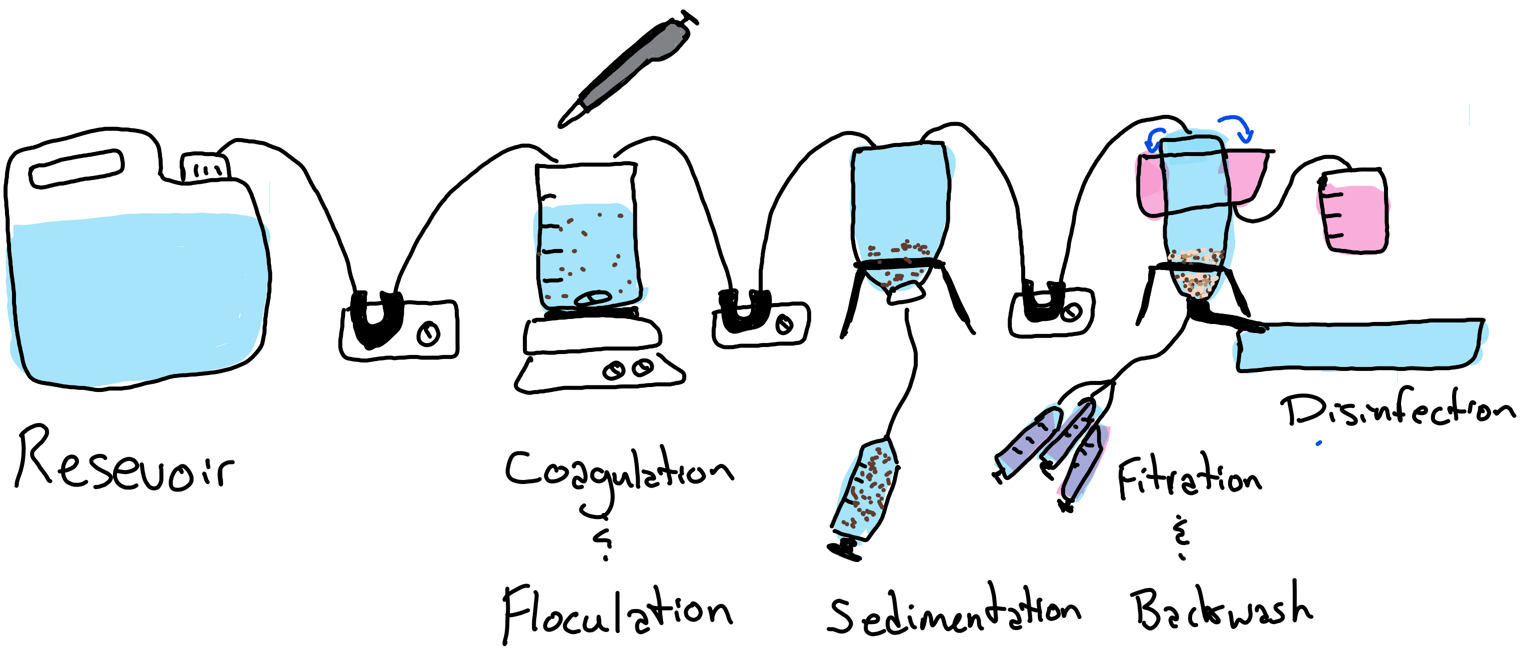
Build and test the drinking water treatment plant design as shown.

If any family or friends drop by, you might explain how the treatment plant works.

You have 30 minutes until the pumps must start treating water.

You have until the end of class to modify and perfect the treatment plant.

Your time starts now.



Drinking Water Treatment Plant Survey

Overall Project

On a scale of 1-10, was this a meaningful assignment? (1-not at all, 10-heck yes!).

On a scale of 1-10, do you feel like you got to be an environmental engineer while building, designing, and iterating on this project? (1-not at all, 10-heck yes!). Explain your answer!

What was your favorite aspect of this project! What skills did you learn and/or develop?

Describe a specific challenge you and your team faced and how you overcame it!

In comparison to other courses, did you enjoy this deeper dive into one big topic with a project, or would you have preferred a broader course covering more topics in environmental engineering?

Drinking Water Treatment Plant Survey

Designing Treatment Plant Process

How satisfied are you with your team's design and the process?

What was your role in this project?

What were the contributions from your teammates?

Do you feel the project helped you apply and conceptualize theoretical knowledge?

Scale of 1-10 with the design of the treatment plant!

Did you have fun? (1 - nope, 10 - lots!)

Did you learn about design and iterating? (1 - nope, 10 - lots!)

Do you feel accomplished (1- nope, 10- absolutely!)

Drinking Water Treatment Plant Survey

Designing Lesson Plans

How satisfied are you with your lesson plan?

What was your role in the lesson plan?

What were the contributions from your teammates?

Did crafting a lesson plan help you understand your topic more clearly?

Scale of 1-10 with the design of the treatment plant!

Did you have fun? (1 - nope, 10 - lots!)

If we could go back in time, do you think our class treatment plant's design and your lesson plans would've helped you learn this material? (1 - nope, 10 - lots!)

Do you feel accomplished (1- nope, 10- absolutely!)

Drinking Water Treatment Plant Survey

Anything else you care to share about your experience on this big project!