"Potamoi": A Device and Data-Driven Mobile App Revolutionizing the Measurement, Storage, and Presentation of Water Quality Metrics

Project ID: MER106

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Abstract

As climate change gradually devastates life on this planet, poor water quality is particularly on the rise. According to a new report from the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), some 2.2 billion people around the world do not have safely-managed drinking water, while 4.2 billion go without safe sanitation services and three billion lack basic hand-washing facilities. Adding to this problem is the fact that individuals have neither convenient nor efficient ways of determining the quality of their water, especially since most water quality devices are expensive, hard to use, and possess complex user-interfaces.

In order to create an effective alternative to current water quality measuring devices, I designed and engineered a simple, all-in-one multi-module device, titled "**Potamoi**," to measure, store, and display real-time water quality data for public use.

I designed "**Potamoi**" based on a three-component design principle:

1) *Control:* Sensor-based Arduino water quality testing device with 20x4 LCD Display-Module
2) *Store :* HC-06 Bluetooth Module which transmits data real-time to MyH_2O, a mobile app interface I created, and Data-Logging Shield Module which stores data for future retrieval
3) *View:* Mobile app interface, "MyH_2O," to display data

I measured and recorded the quality of water in the Allegheny, Monongahela, and Ohio Rivers, three rivers in Pittsburgh, my hometown. My component-based Arduino-device consists of pH, temperature, TDS (Total Dissolved Solids), and turbidity(Cloudiness of the water) sensors for different points-of-testing.

I sampled 5 locations in each of the three rivers. I tested each sample 200 times with four sensors each time. I validated the accuracy of my device by conducting a comparative analysis: I compared water quality data produced by my device with that generated by an industrial-grade water quality meter.

Based on the results of my statistical analysis, my device invention relatively accurately tests water quality.
The mobile app I created, called "MyH_2O," displays water quality measurements in real-time on a user-friendly interface accessible to anyone, anytime, anywhere. "Potamoi" can successfully help individuals around the world access and view much-needed water quality measurements.

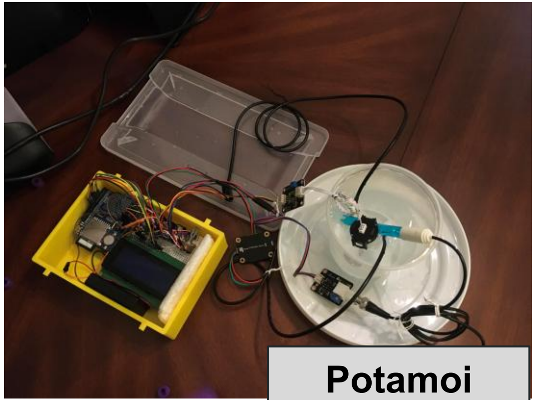
“Potamoi” and “MyH_2O” in Action - Preview

Material to checkout prior to/after the presentation

- Please click below to view a brief video of my device, “Potamoi”, and my app, “MyH_2O”, in action before reading this document

  https://www.youtube.com/watch?v=frVQgyZhddg

  Click here to view my project report (a detailed view of my work)



Potamoi

Agenda

Background

Engineering Approach

- 4,010 of Pennsylvania’s public water systems violated EPA water quality standards in 2019

- Poor mining practices negatively affect water quality
    - Many communities are left with water containing unsafe levels of iron, sulfate, and other mineral compounds

http://pennsylvaniawatersheds.org/our-work/abandoned-mine-drainage/

Rationale

Engineering Approach

Lack of access to clean water is a global issue. We even see this in the most developed country in the world, the United States. Living in Pittsburgh, Pennsylvania all of my life and seeing how the Allegheny, Monongahela, and Ohio rivers are such staples of the city, I was motivated to investigate current commercially available devices for measuring water quality.

Problem Scope

Engineering Approach

- Many water quality devices do not possess the greater ability to record and/or access historical water quality data specific to users
- Interfaces universally lack simplicity
- Average costs are significantly high for devices with multiple parameters such as temperature, pH, TDS, and Turbidity (approximately $20 to $4000)
    - Low-cost devices are un-reliable
    - Reliable devices are expensive

Engineering Goal

Engineering Approach

- Engineering Goal:
  - Tackle the three aforementioned challenges
  - Include beneficial aspects of currently available devices (speed of readings, parameters)

- My own home made device (“Potamoi’s”) features:
  - Includes 4 parameters: temperature, TDS, turbidity, and pH
  - Logs data on to an SD card with a date and time stamp for easy access

- My own home made mobile app (“MyH_2O’s”) features:
  - Shows the date of when the water quality measurement took place
  - Shows current and past lists of water quality measurements
  - Marks the location of where the water quality measurement took place on a map

Project Roadmap

Experimental Group (Potamoi/MyH_2O)

Collect

- I will collect 15 water samples from the 3 rivers of Pittsburgh:
- Ohio River – Five samples
- Monongahela River – Five samples
- Allegheny River – Five samples

Design & Build

- Create "Potamoi" and "MyH_2O" for the measurement and presentation of water quality data

Test

- I will test "Potamoi" in each of the water samples
- "MyH_2O" will display the data with averages and location identification

Control Group (Industrial-Grade Device)

Send

I will send half of each of the 15 samples I collected to the organization for testing:

- Ohio River – Five locations
- Monongahela River – Five Locations
- Allegheny River – Five Locations

Test

- The organization will test the water samples with their industrial-grade devices; They will email the results to me so I can compare them to "Potamoi's" data

Analyze

- I will use a Two Factor ANOVA and Standard Error Bars to analyze if there is significant variation between "Potamoi's" and the industrial-grade devices' data

Research on Currently Available Devices

Engineering Approach

Product Name	Parameters measured	COST (US$)	Drawback
90XL Dialysis Technician Meter	pH, Temperature, Electrical Conductivity, Pressure	$1700.00	Not commercially available
Thermo Scientific VSTAR94 – Orion Versa Star Pro Meter Kit (CONTROL FOR PH)	pH, Electrical Conductivity, TDS, Salinity	$3724.00	Very expensive, not commercially available
CAT. NO. 44740-88 , PORTABLE TURBIDIMETER Model 2100P ISO by Hach (CONTROL FOR TURBIDITY)	Turbidity	$1396.00	Can only conduct one reading at a time
Oven; 2.3 cu. Ft., General Protocol, Gravity Convection, Heratherm, Coated Steel, 120 V (CONTROL FOR TDS")	TDS	$1658.00	Not commercially available
YSI ProQuatro Multiparameter Meter	Dissolved Oxygen, Electrical Conductivity, Salinity, Resistivity, TDS, Temperature	$2784.00	Very expensive
Bluelab Guardian Monitor	Electrical conductivity/temperature/pH	$411	Many reviews on Amazon.com say that the probes do not work

Industrial-Grade Devices (Control Group)

Engineering Approach

TDS Meter

$1658.00

Turbidimeter

$1396.00

pH Meter

$3724.00

PC: The organization I sent the water samples to

Selection of Water Quality Parameters/Characteristics

Engineering Approach

Temperature

PC: https://safewater.org

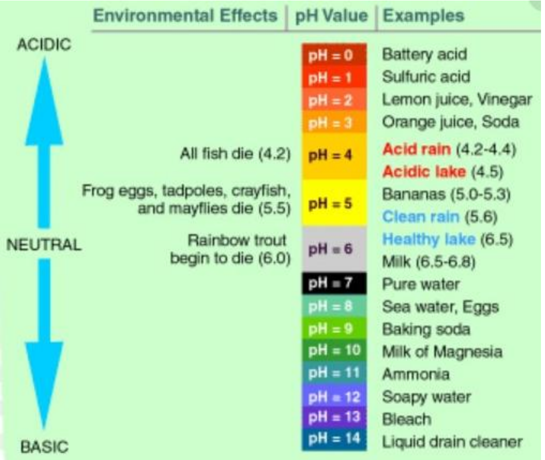
TDS – Total Dissolved Solids

Level of TDS (milligrams per litre)	Rating
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

PC: https://safewater.org

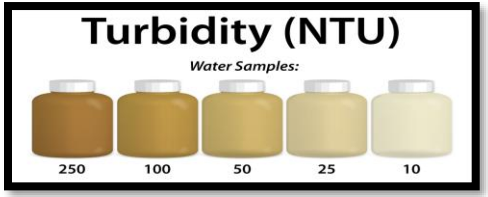
Parameters

pH – Potential of Hydrogen



PC: https://www.usgs.gov

Turbidity – Cloudiness



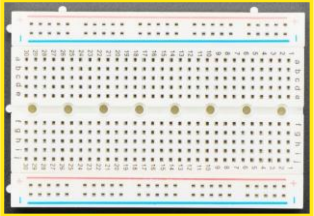
PC: https://www.usgs.gov

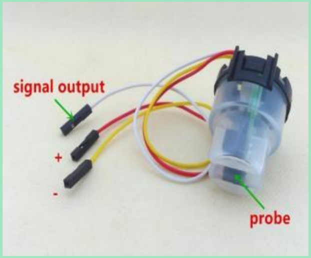
Materials and Economics

Engineering Approach

Materials	Cost	Total
Arduino Uno	$15	$15
Sensors		
Temperature	$6	$6
pH	$15	$15
TDS	$12	$12
Turbidity	$8	$8
LCD Display	$10	$10
Potentiometer	$2	$2
Data Logging		
Data-Logging Shield	$5	$5
Circuity Components		

Materials	Cost	Total
Resistors (220Ohm, 4.7K Ohm)	$.50 *4	$2
Jumper Wires	$2	$2
Breadboard	$7	$7
HC-06 Bluetooth Module	$4	$4
Miscellaneous		
Battery pack	$2	$2
App-Building		
Figma	$0	$0
Bravo Studio	$0	$0
Airtable	$0	$0
Grand Total		**$90**

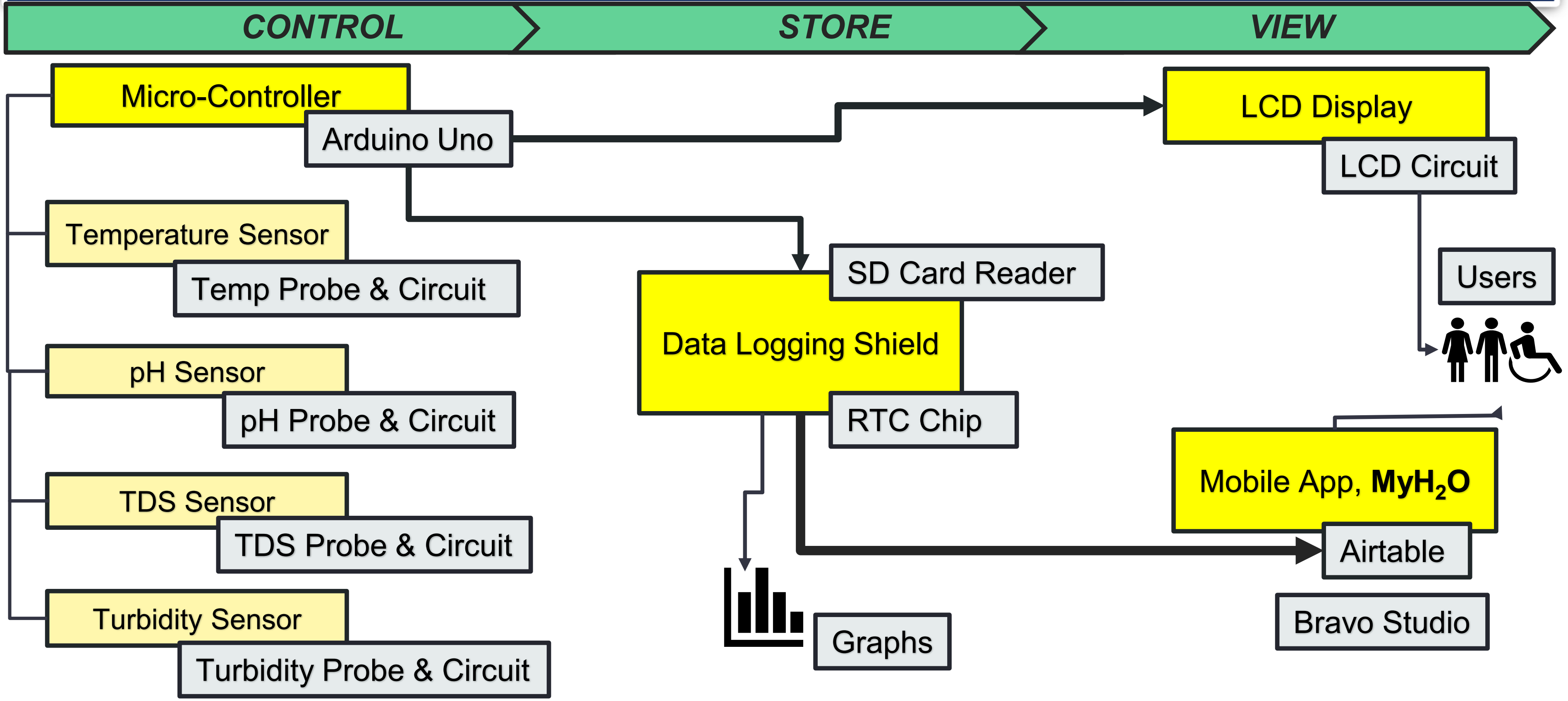




PC : Amazon.com

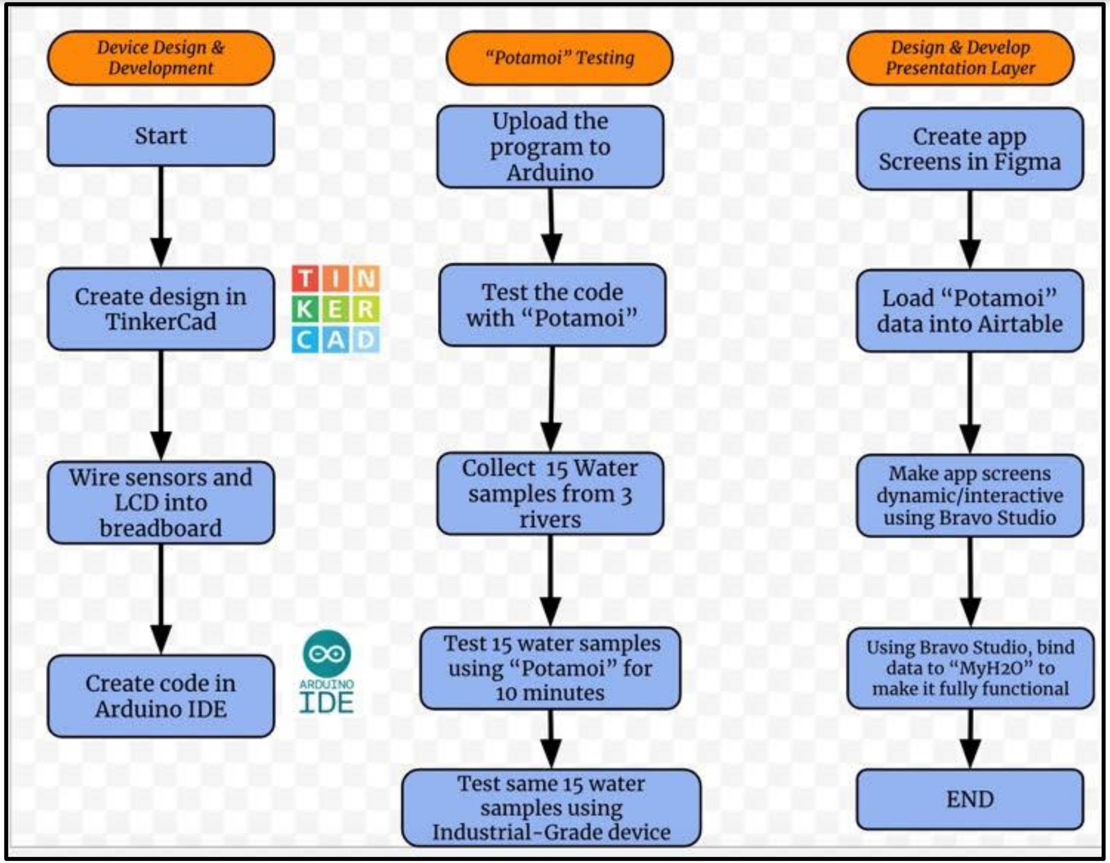
Engineering Design – “Potamoi” on a Page

Engineering Approach



“Potamoi” and “MyH$_2$O” Designing and Testing Flowchart

Procedural Plan



I got 5 different users to use my “MYH$_2$O” app. Their overall feedback is below:

- Very intuitive, easy to use
- Very efficient that water quality can be seen immediately after testing
- Would like to see graphs in “MyH$_2$O”
- Would like to see side by side data comparison between “Potamoi” data and industrial grade device’s data

External Libraries and Interferences/Errors Encountered

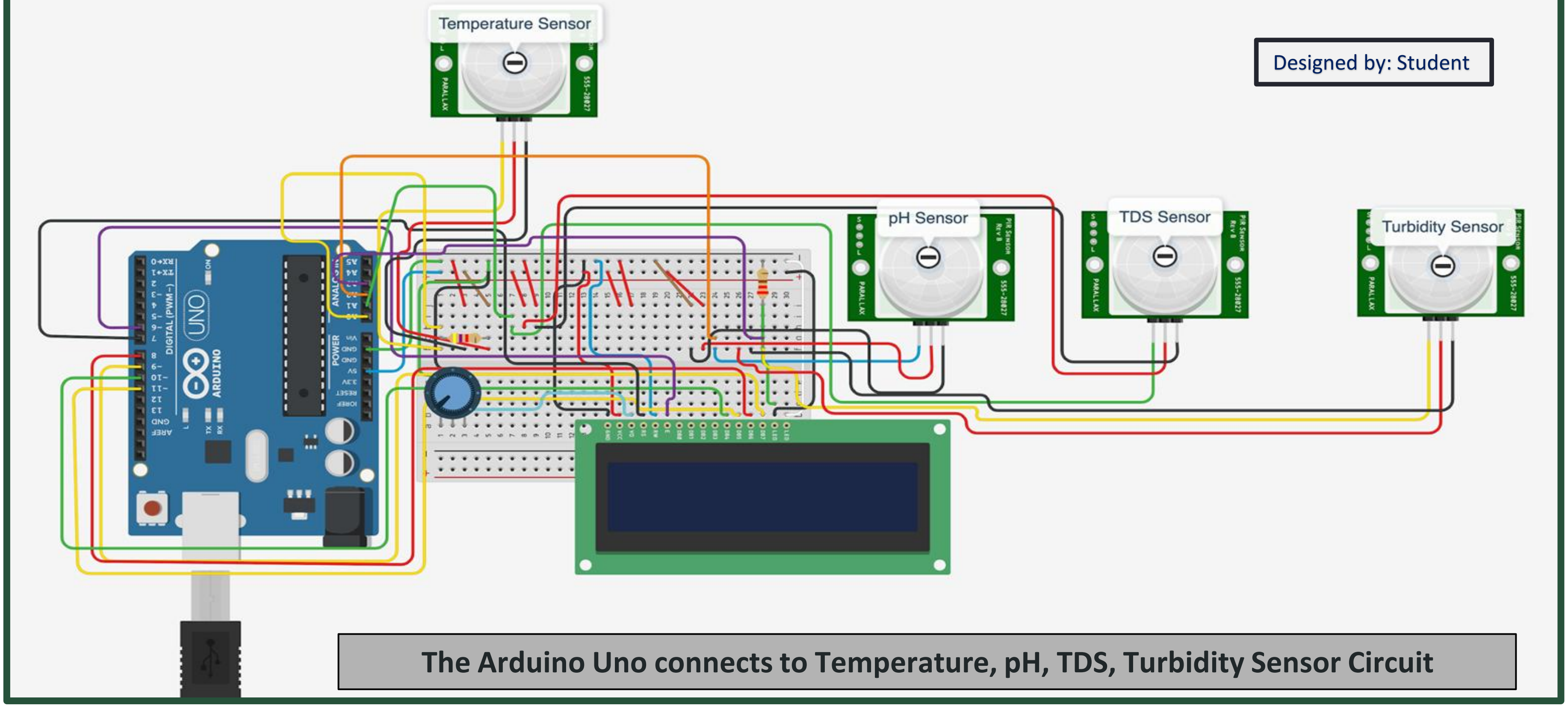
Procedural Plan

- External Libraries:
  - RTCLib and Wire – Used to communicate with the RTC Clock on the Datalogging Shield
  - SD – Used to communicate with the SD Card Reader on the Datalogging Shield
  - OneWire and DallasTemperature – Used to communicate with DS18B20 Temperature Sensor
  - GravityTDS – Used to communicate with the TDS Sensor
  - EEPROM – Used to safely transfer data from Arduino to any external sources
  - LiquidCrystal – Used to communicate with the LCD Screen

- Errors/Interferences:
  - Receiving errors when trying to upload Arduino code using macOS; resolved by switching to Windows and using a different Arduino Software
  - Blynk and LCD display could not run simultaneously

Circuit Diagram designed using Tinkercad

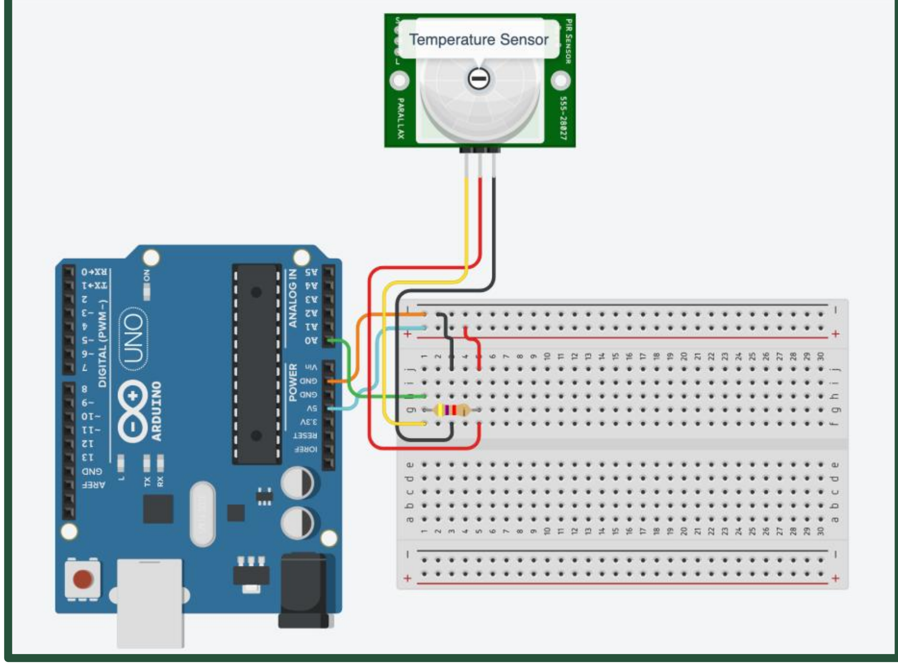
Procedural Plan

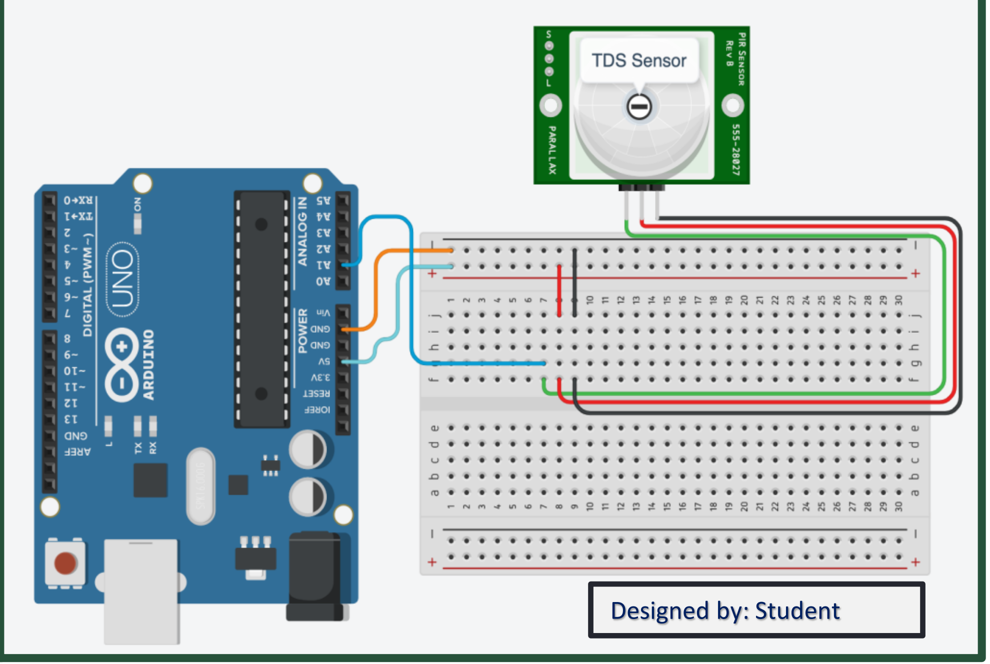


The Arduino Uno connects to Temperature, pH, TDS, Turbidity Sensor Circuit

Circuit Diagram Breakdown designed using Tinkercad

Procedural Plan



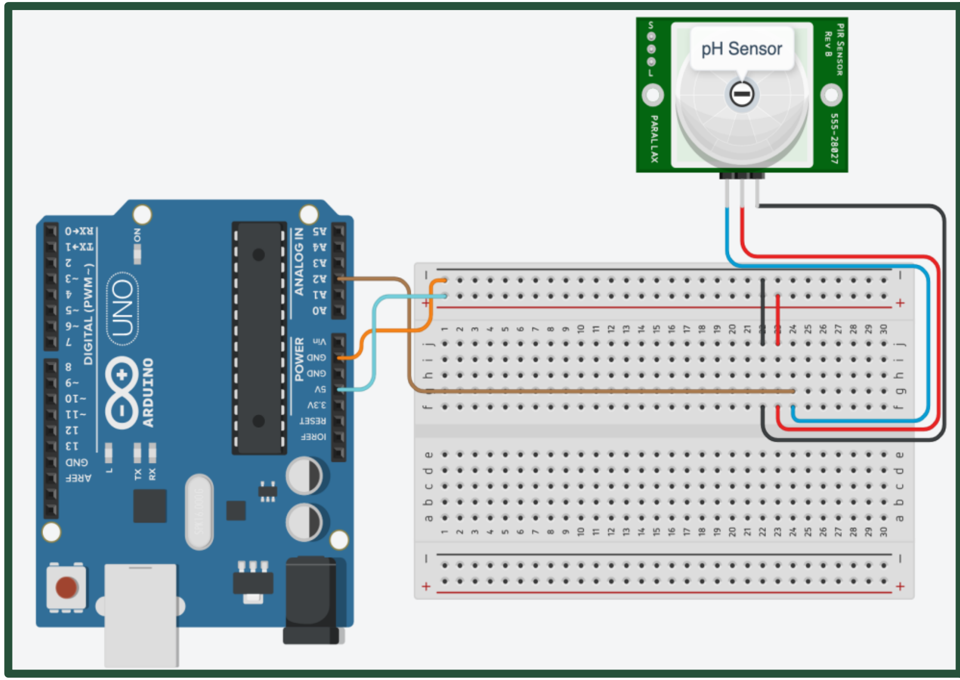


Temperature Sensor Circuit

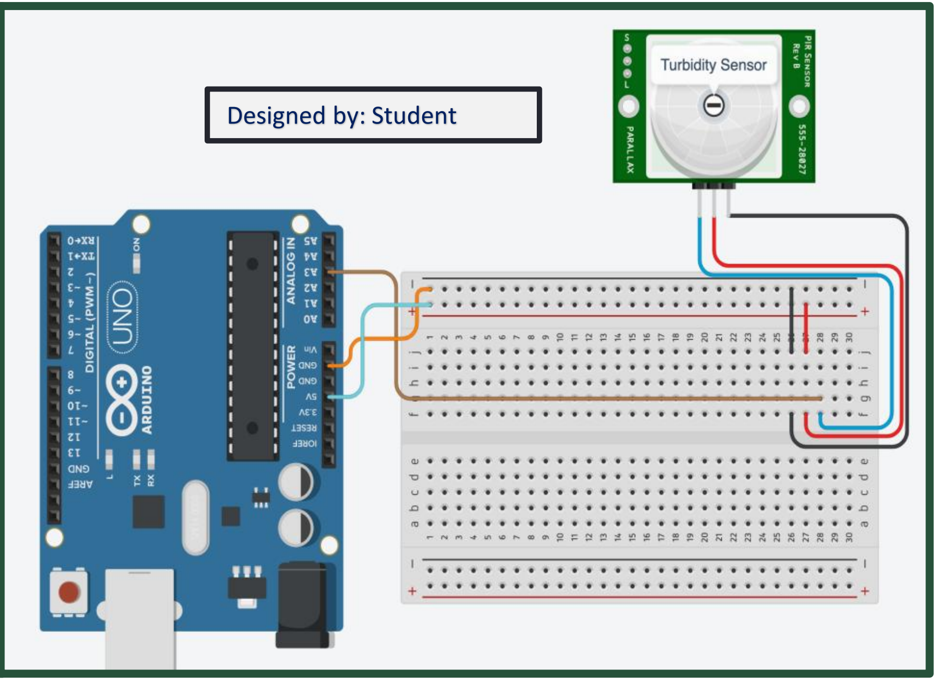
TDS Sensor Circuit

Circuit Diagram Breakdown (cont.)

Procedural Plan



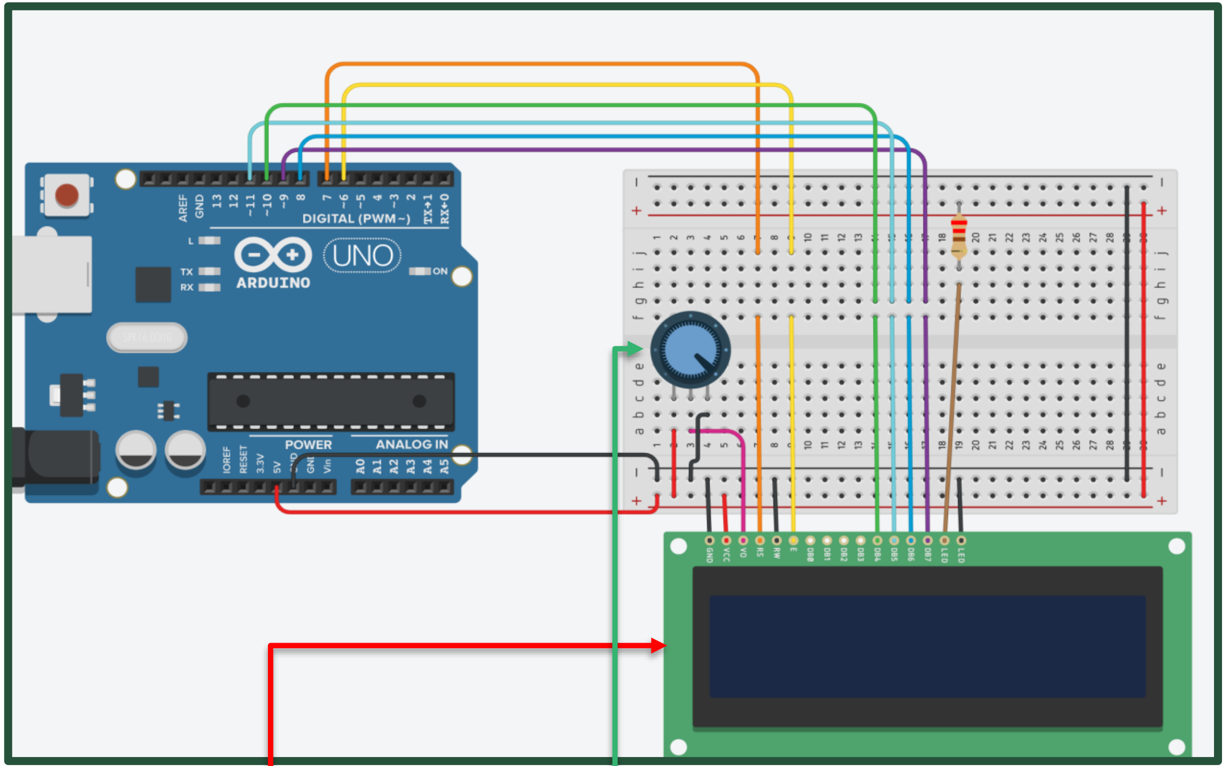
pH Sensor Circuit



Turbidity Sensor Circuit

Circuit Diagram Breakdown (cont.)

Procedural Plan



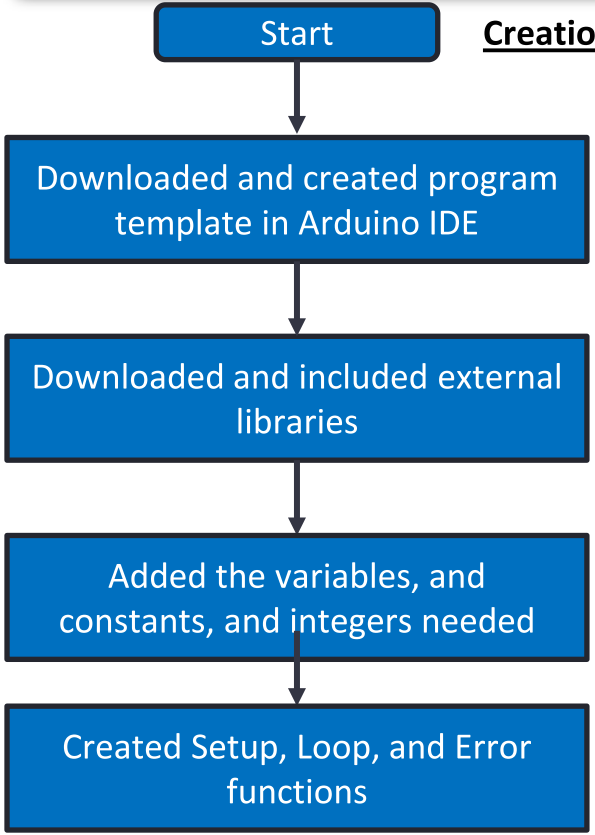
LCD Display and Potentiometer Circuit

PC & Designed by: Student

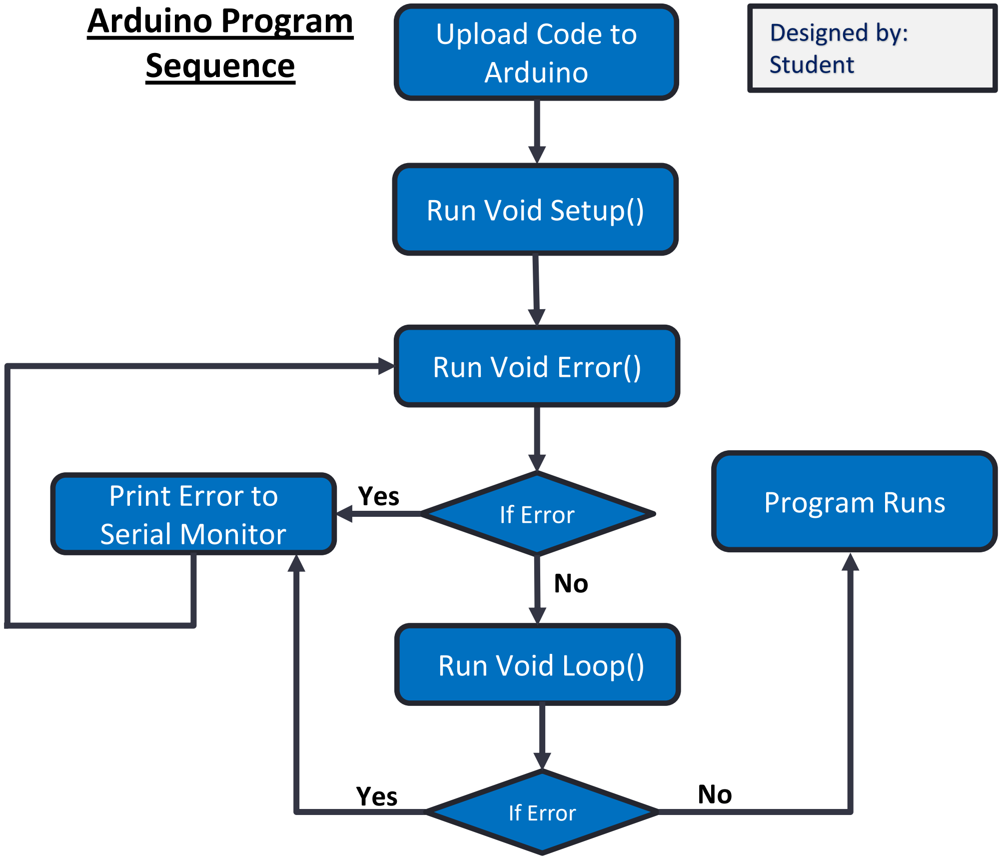
Arduino Code Creation and Sequence Flowcharts

Procedural Plan

Creation of Arduino Code



Arduino Program Sequence

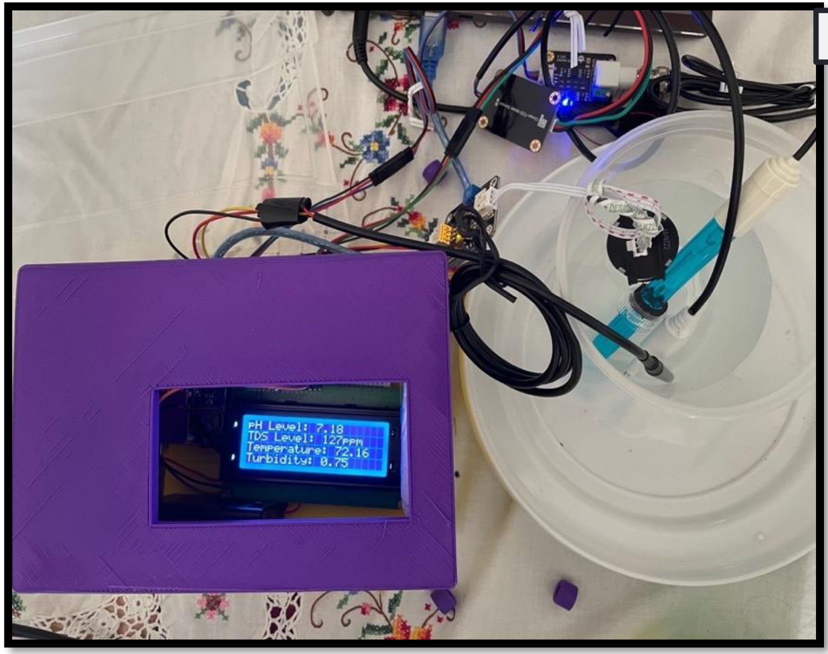


Designed by:
Student

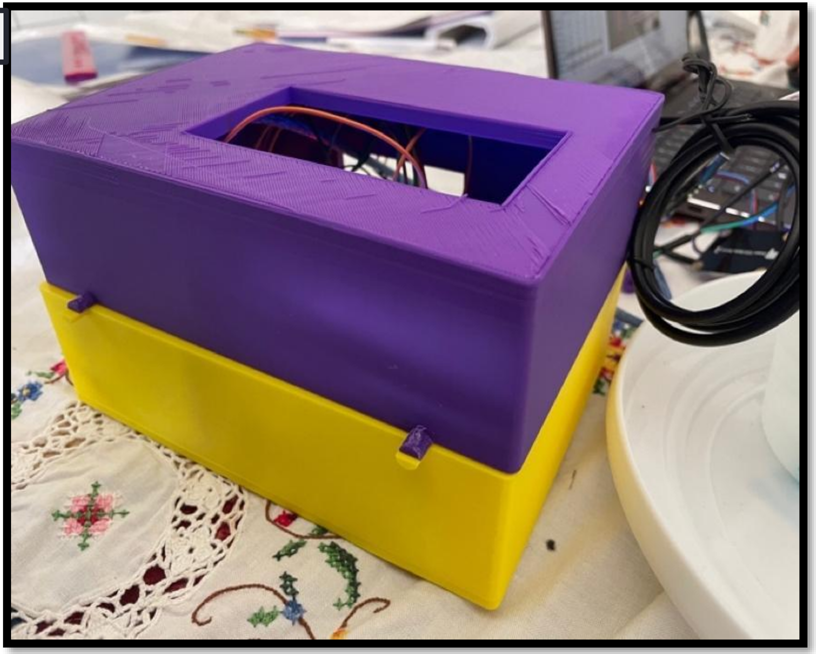
“Potamoi:” Finished Product

Construction feasible and cost effective

PC: Student



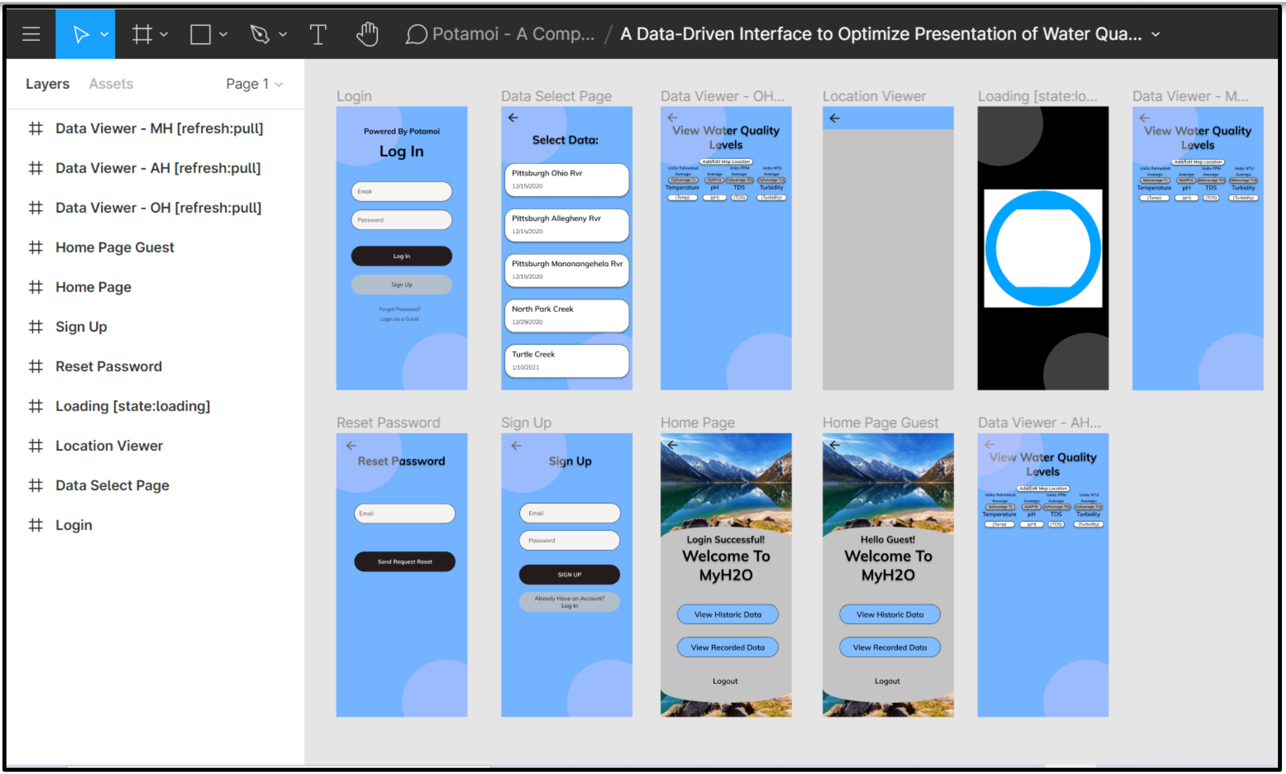
Top View While Testing



Front View While Testing

Prototyping Steps for Mobile App – Creating App Screen Designs

Procedural Plan



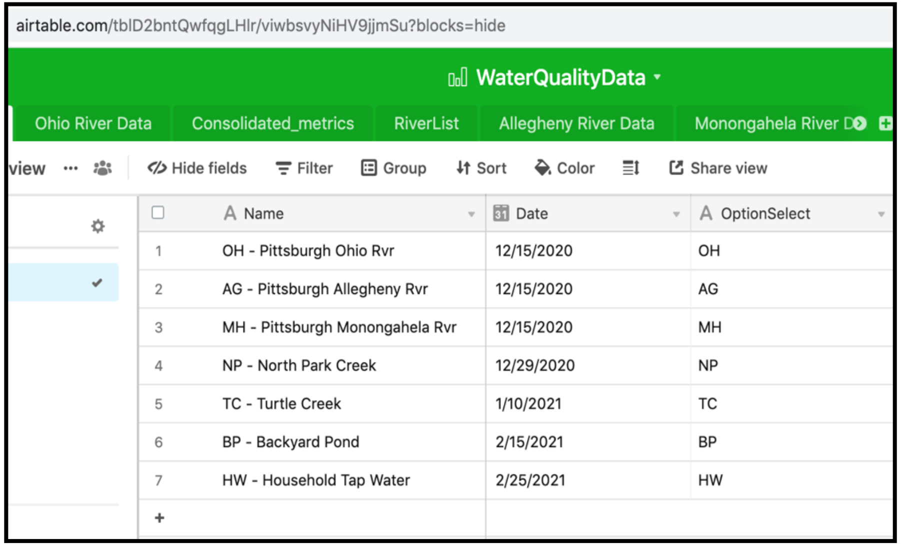
PC: figma.com

App Page Designs in Figma

PC: Student

Prototyping Steps for Mobile App – Loading Data to Airtable

Procedural Plan



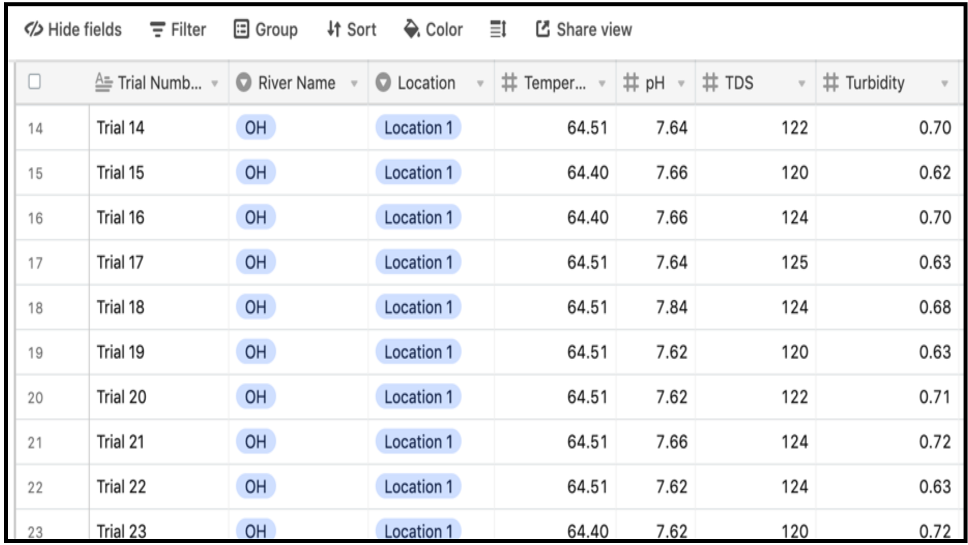
airtable.com/tblD2bntQwfqgLHlr/viwbsvyNiHV9jjmSu?blocks=hide

WaterQualityData

Ohio River Data | Consolidated_metrics | RiverList | Allegheny River Data | Monongahela River D

view ··· Hide fields Filter Group Sort Color Share view

	Name	Date	OptionSelect
1	OH - Pittsburgh Ohio Rvr	12/15/2020	OH
2	AG - Pittsburgh Allegheny Rvr	12/15/2020	AG
3	MH - Pittsburgh Monongahela Rvr	12/15/2020	MH
4	NP - North Park Creek	12/29/2020	NP
5	TC - Turtle Creek	1/10/2021	TC
6	BP - Backyard Pond	2/15/2021	BP
7	HW - Household Tap Water	2/25/2021	HW



Hide fields Filter Group Sort Color Share view

	Trial Numb...	River Name	Location	Temper...	pH	TDS	Turbidity
14	Trial 14	OH	Location 1	64.51	7.64	122	0.70
15	Trial 15	OH	Location 1	64.40	7.66	120	0.62
16	Trial 16	OH	Location 1	64.40	7.66	124	0.70
17	Trial 17	OH	Location 1	64.51	7.64	125	0.63
18	Trial 18	OH	Location 1	64.51	7.84	124	0.68
19	Trial 19	OH	Location 1	64.51	7.62	120	0.63
20	Trial 20	OH	Location 1	64.51	7.62	122	0.71
21	Trial 21	OH	Location 1	64.51	7.66	124	0.72
22	Trial 22	OH	Location 1	64.51	7.62	124	0.63
23	Trial 23	OH	Location 1	64.40	7.62	120	0.72

Data from "Potamoi" Loaded into Airtable

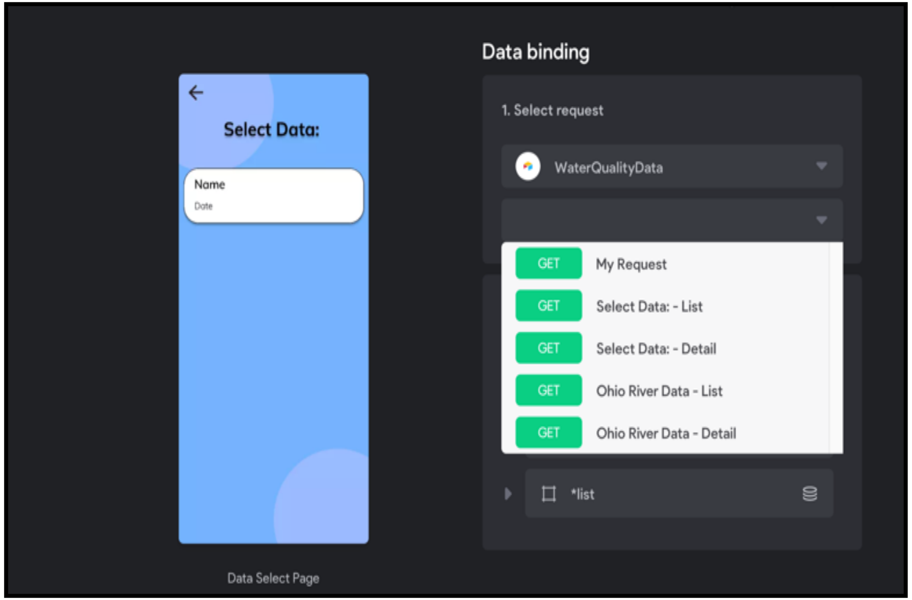
Airtable

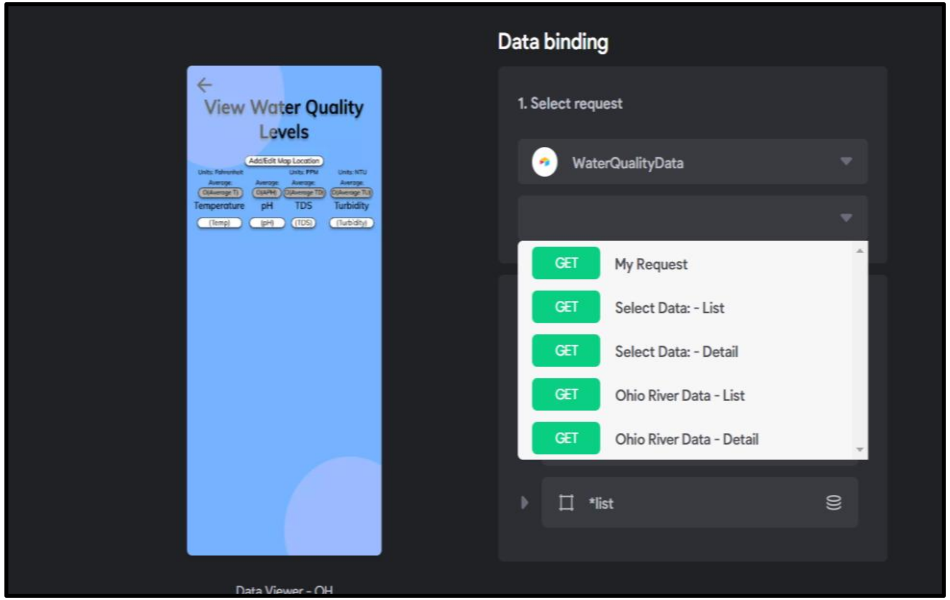
PC: airtable.com

PC: Student

Prototyping Steps for Mobile App – Binding Data to App

Procedural Plan





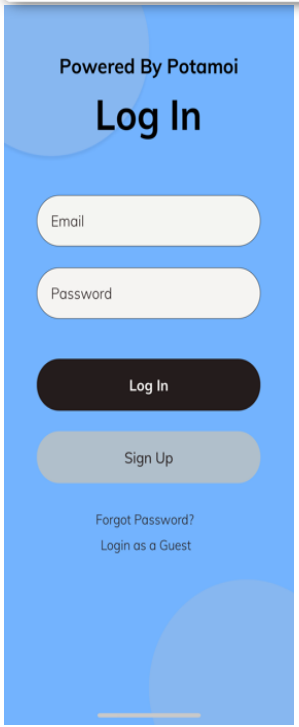
Binding Data to App Using Bravo Studio

PC: bravostudio.app

PC: Student

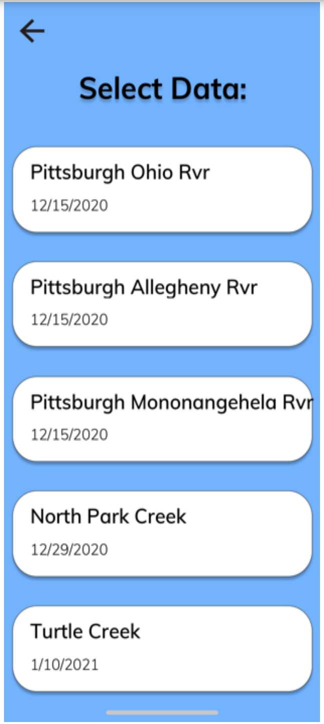
Results: Data-Driven Interface, “MyH$_2$O”

Final Mobile App

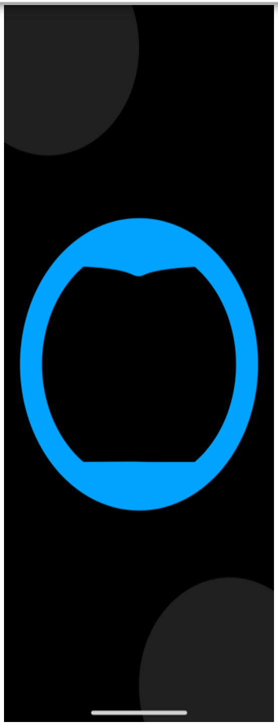


Login Screen

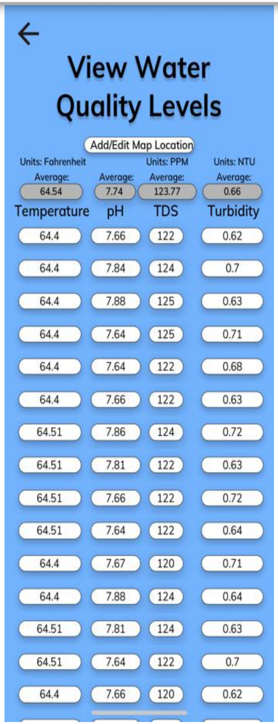
Home Screen



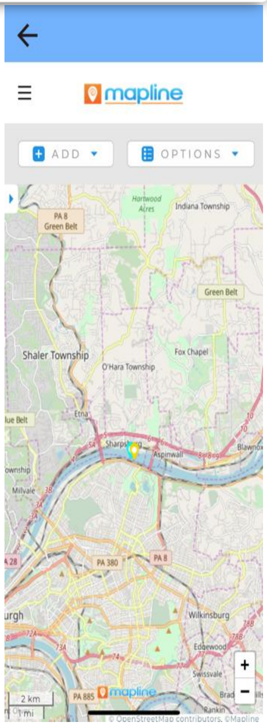
User selects the data they want to view



Custom loading screen



Data is populated



Add/edit location of data

Designed by Student

Data Received from “Potamoi”

=~=~=~=~=~=~=~=~=~=~=~= PuTTY log 2021.03.11 18:20:26 =~=~=~=~=~=~=~=~=~=~=~=

Initializing SD card...

Date & Time	Temp (In Fahrenheit)	pH	TDS (In PPM)	Turbidity (In NTU)
2021/3/11 (Thursday) 6:20:2	74.86	6.94	4	0.72
2021/3/11 (Thursday) 6:20:3	74.86	6.92	10	0.72
2021/3/11 (Thursday) 6:20:4	74.75	6.96	4	0.66
2021/3/11 (Thursday) 6:20:5	74.86	6.94	10	0.72
2021/3/11 (Thursday) 6:20:6	74.75	6.94	10	0.67
2021/3/11 (Thursday) 6:20:7	74.75	6.92	4	0.73
2021/3/11 (Thursday) 6:20:8	74.75	6.96	10	0.66
2021/3/11 (Thursday) 6:20:9	74.75	6.96	4	0.73
2021/3/11 (Thursday) 6:20:10	74.75	6.94	10	0.68
2021/3/11 (Thursday) 6:20:11	74.75	6.96	6	0.68
2021/3/11 (Thursday) 6:20:12	74.86	6.94	12	0.74
2021/3/11 (Thursday) 6:20:13	74.75	6.94	4	0.68
2021/3/11 (Thursday) 6:20:14	74.86	6.92	4	0.72
2021/3/11 (Thursday) 6:20:15	74.86	6.94	10	0.66
2021/3/11 (Thursday) 6:20:16	74.86	6.92	4	0.72
2021/3/11 (Thursday) 6:20:17	74.86	6.92	10	0.66
2021/3/11 (Thursday) 6:20:18	74.86	6.94	4	0.72
2021/3/11 (Thursday) 6:20:19	74.86	6.92	10	0.74
2021/3/11 (Thursday) 6:20:20	74.86	6.94	6	0.68
2021/3/11 (Thursday) 6:20:21	74.86	6.94	8	0.73
2021/3/11 (Thursday) 6:20:22	74.86	6.94	10	0.68
2021/3/11 (Thursday) 6:20:23	74.86	6.94	4	0.74
2021/3/11 (Thursday) 6:20:24	74.97	6.92	10	0.68
2021/3/11 (Thursday) 6:20:25	74.86	6.94	4	0.74
2021/3/11 (Thursday) 6:20:26	74.86	6.94	10	0.66
2021/3/11 (Thursday) 6:20:27	74.86	6.96	6	0.66

This is a sample of the water quality data produced by “Potamoi”.
The data is being stored on an SD card and shown on the screen through PuTTY.

Data columns

Column 1 – Date and Time

Column 2 – Temperature reading (F)

Column 3 – pH

Column 4 – TDS (in PPM)

Column 5 – Turbidity (in NTU)

Data Received from Potamoi (Averages)

Data Analysis

I conducted 200 trials for each sample of water. Then, as the industrial-grade device had only 5 samples for each location, I took the average of every 40 samples (1-40, 41-80, 81-120, 121-160, 161-200) to have five samples even though I conducted 200 trials.

Sample ID	pH							Turbidity (NTU)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Std. Dev.	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Std. Dev.
OH1	6.91	6.93	6.93	6.96	6.96	6.938	0.021679	0.98	0.99	1.03	0.96	0.98	0.988	0.02588
OH2	7.02	7.02	7.01	7.11	6.91	7.014	0.070922	0.83	0.83	0.82	0.87	0.77	0.824	0.035777
OH3	7.03	6.99	6.92	6.99	6.9	6.966	0.054129	0.85	0.86	0.84	0.81	0.79	0.83	0.029155
OH4	6.91	6.91	6.99	6.99	7.01	6.962	0.048166	0.72	0.71	0.7	0.69	0.72	0.708	0.01304
OH5	7	7.03	6.95	7	6.98	6.992	0.029496	0.81	0.78	0.83	0.85	0.87	0.828	0.034928
MH1	7.07	7.07	7.08	7.08	7.08	7.076	0.005477	0.74	0.71	0.73	0.73	0.76	0.734	0.0181659
MH2	6.8	6.8	6.75	6.75	6.74	6.768	0.029496	0.6	0.5	0.53	0.54	0.56	0.546	0.0371484
MH3	6.94	7	6.9	6.91	6.87	6.936	0.60249	0.4	0.41	0.42	0.45	0.38	0.412	0.0258844
MH4	6.98	6.99	6.9	6.97	6.98	6.968	0.039623	0.4	0.4	0.52	0.43	0.41	0.432	0.0506952
MH5	7	6.9	6.98	7.03	7.02	6.966	0.063087	0.51	0.6	0.52	0.51	0.53	0.534	0.037815
AH1	7.05	7.05	7.01	7.01	7.03	7.03	0.02	0.98	0.97	1.02	0.99	0.96	0.984	0.023022
AH2	7.05	7.01	7.04	7.03	7.03	7.032	0.014832	1.07	1.01	0.9	1.05	1.03	1.012	0.066483
AH3	7.04	7.04	7.06	7.05	7.05	7.048	0.008367	0.71	0.75	0.65	0.63	0.71	0.69	0.04899
AH4	7.12	7.07	7.07	7.08	7.08	7.084	0.020736	0.8	0.71	0.72	0.69	0.61	0.706	0.068044
AH5	7.1	7.1	7.14	7.13	7.13	7.12	0.018708	0.6	0.67	0.68	0.59	0.58	0.624	0.047223

Data Received from Potamoi (Averages) cont.

Data Analysis

Sample ID	TDS (PPM)							Temperature (Fahrenheit)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Std. Dev.	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Std. Dev.
OH1	122.75	123.075	124	124.525	124.6216	123.7943	0.846855	64.44	64.5	64.53	64.62	64.64	64.54528	0.08273
OH2	135.75	135.95	136	135.75	135.946	135.888	0.11984	66.13	66.23	66.31	66.42	66.5	66.31784	0.149023
OH3	132.525	132.575	132.7	132.925	123.568	130.877	4.07869	64.48	64.63	64.73	64.84	65.14	64.76224	0.250888
OH4	122.7	123.1	123.05	125.65	125.73	124.03	1.50884	64.97	65.03	65.16	65.2	65.27	65.12749	0.125168
OH5	120.5	123.05	120.15	120.703	120.703	120.409	0.20726	66.96	67.07	67.13	67.2	67.2	67.11165	0.098877
MH1	160.95	161.4	161.75	161.55	161.846	161.499	0.3526	66.95	67.07	67.18	67.27	67.38	67.16978	0.165751
MH2	171.1	166.45	166.625	166.85	167.281	167.661	1.94734	67.44	67.61	67.64	67.72	67.75	67.63175	0.123072
MH3	183.25	182.95	182.925	183.05	183.077	183.05	0.12879	70.38	70.4	70.43	70.46	70.49	70.43512	0.043628
MH4	166.8	166.525	167.15	167.175	167.654	167.061	0.42656	68.9	68.99	69.08	69.19	69.23	69.07835	0.136749
MH5	187.25	186.875	186.75	186.775	186.846	186.899	0.20257	70.35	70.38	70.43	70.45	70.52	70.42723	0.062462
AH1	119.35	117.9	117.7	117.5	117.6757	118.0251	0.754077	66.2865	66.4055	66.52625	66.573	66.63778	66.48576	0.140183
AH2	126.025	126.65	126.725	126.975	127.7	126.815	0.605857	66.13125	66.16425	66.29475	66.36975	66.42586	66.27717	0.127508
AH3	129.5	130.7	131.625	131.675	131.5135	131.0027	0.928697	67.1715	67.2485	67.2595	67.31475	67.35222	67.26929	0.068984
AH4	135.25	132.65	132.5	132.6	132.2	133.04	1.247698	69.10375	69.18025	69.273	69.31975	56.68	66.71135	5.608316
AH5	121.45	117.05	117.05	117.05	117.1351	117.947	1.958568	67.32125	67.383	67.45	67.517	67.58422	67.45109	0.10436

Control Group: Data from Industrial-Grade Devices

Data Analysis

I sent half of my samples to the organization which has the industry grade devices to perform testing with the same parameters of my device. Instead of 200 trials they tested only 5 trials for each sensor and for each sample (This was why I created 5 averages)

Sample Id	pH					Turbidity (NTU)					TDS (mg/L)				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
OH1	6.95	6.96	6.96	6.96	6.96	1	0.82	1.02	1.25	1.08	137.6	133.6	123.6	118.4	105.6
OH2	6.99	7	7	7	7.01	1.1	1.01	0.75	0.49	0.69	136.8	81.6	124.0	120.0	113.2
OH3	6.99	6.99	6.99	6.99	7	1	0.76	0.97	0.78	0.87	139.6	117.6	119.2	118.4	120.0
OH4	6.96	6.97	6.97	6.98	6.98	0.8	0.6	0.75	0.69	0.84	114.0	118.4	89.6	116.0	124.4
OH5	6.99	6.99	6.99	6.99	7	0.9	0.85	0.86	0.75	0.94	121.2	114.4	100.4	106.0	117.2
MH1	7.13	7.1	7.07	7.05	7.06	0.77	0.7	0.81	0.73	0.7	228.0	204.0	211.2	214.8	190.8
MH2	6.75	6.77	6.78	6.78	6.8	0.51	0.59	0.54	0.53	0.52	168.0	191.6	204.4	184.8	191.2
MH3	6.82	6.84	6.92	6.93	6.94	0.47	0.42	0.44	0.49	0.44	194.4	201.6	192.8	198.8	208.4
MH4	6.94	6.96	6.96	6.98	6.98	0.45	0.45	0.43	0.38	0.38	214.0	188.0	188.8	188.0	208.4
MH5	6.98	6.99	6.99	7	7	0.47	0.46	0.65	0.54	0.46	201.2	203.2	208.8	194.8	186.0
AH1	7.02	7.02	7.02	7.02	7.03	1.2	1.06	1.09	1.12	1.11	169.2	117.6	183.2	187.2	133.2
AH2	7.03	7.04	7.05	7.05	7.06	1	1	1	1.04	1.06	128.0	138.4	133.6	138.4	132.4
AH3	7.03	7.04	7.05	7.05	7.05	0.73	0.6	0.63	0.74	0.71	154.4	117.2	102.8	104.8	137.6
AH4	7.06	7.07	7.07	7.08	7.09	0.61	0.71	0.61	0.72	0.57	161.6	98.0	139.2	141.6	153.2
AH5	7.08	7.09	7.09	7.1	7.1	0.57	0.61	0.62	0.59	0.63	138.0	130.4	140.8	133.2	127.6

Statistical Analysis: Two-Factor ANOVA and Standard Error

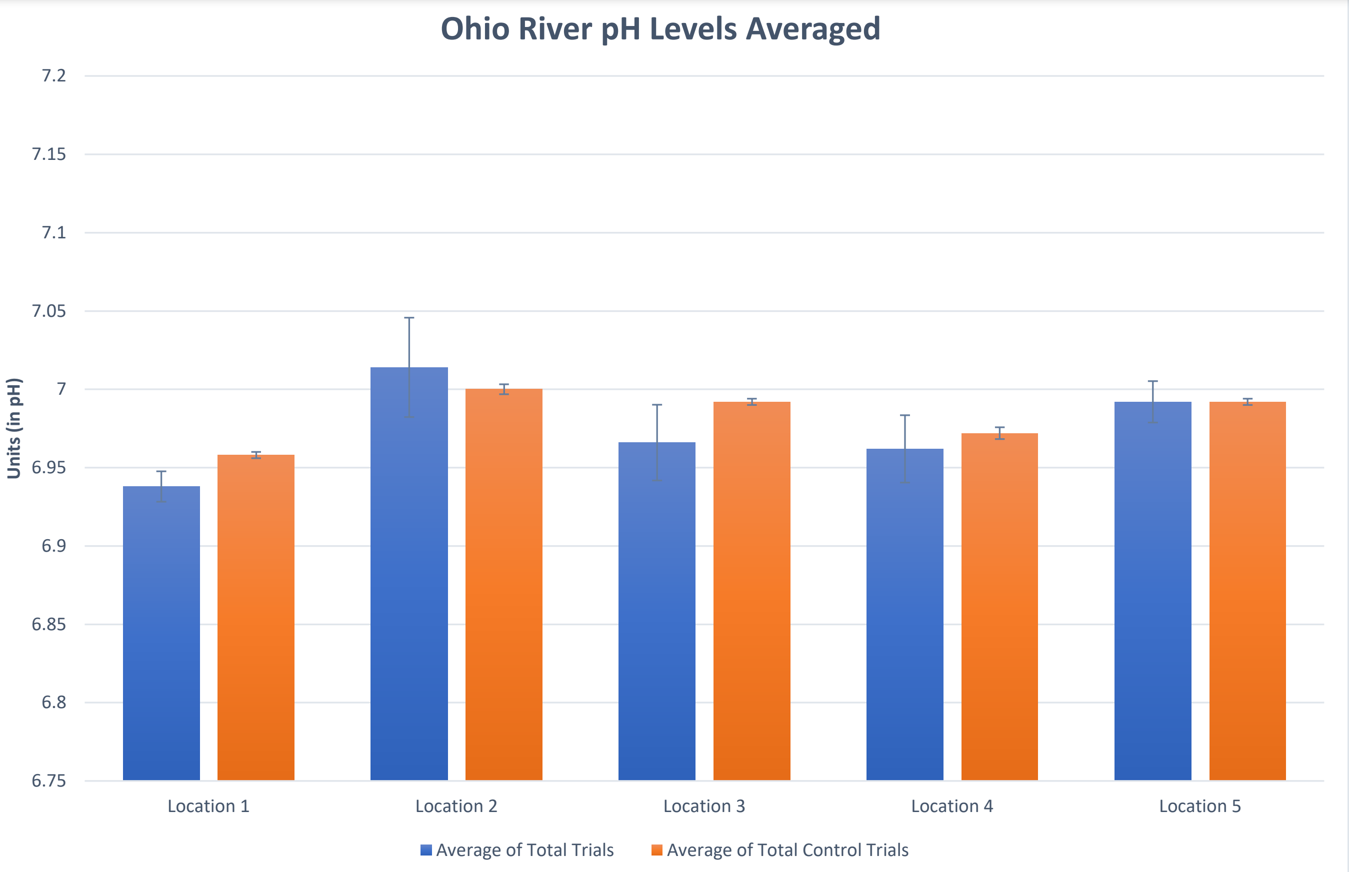
Analytical Approach

- Two Factor ANOVA:
  - Determines if two independent variables (Type of group and location) have an effect on a dependent variable ("Potamoi" and industrial-grade data)
  - Calculates a p-value, f-value, and f-crit
  - If the p-value is less than 0.05, and the f-value is greater than the f-crit, then there was significant variation between the two groups

- Standard Error Bars:
  - If two error bars on a graph from each group overlap, then there was significant variation between those two groups

Results Interpretation: Ohio River pH Levels

Analytical Approach



BLUE bar – “Potamoi” Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter

- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Ohio River pH Levels

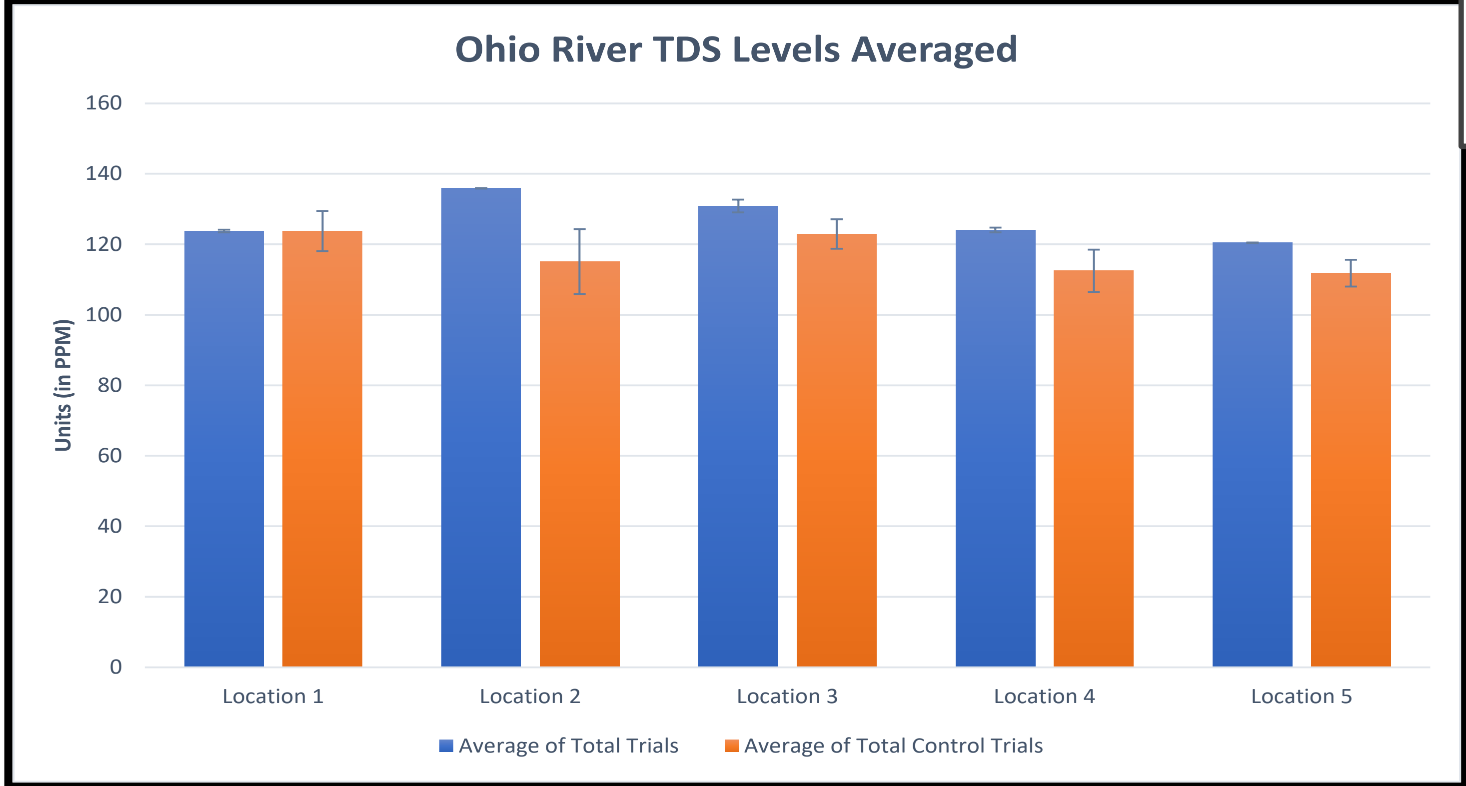
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	34.79	35	34.96	34.86	34.96	174.57
Average	6.958	7	6.992	6.972	6.992	6.9828
Variance	2E-05	5E-05	2E-05	7E-05	2E-05	0.000279
Treatment						
Count	5	5	5	5	5	25
Sum	34.69	35.07	34.83	34.81	34.96	174.36
Average	6.938	7.014	6.966	6.962	6.992	6.9744
Variance	0.00047	0.00503	0.00293	0.00232	0.00087	0.002651
Total						
Count	10	10	10	10	10	
Sum	69.48	70.07	69.79	69.67	69.92	
Average	6.948	7.007	6.979	6.967	6.992	
Variance	0.000329	0.002312	0.001499	0.00109	0.000396	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.000882	1	0.000882	0.747458	0.392438	4.084746
Columns	0.020572	4	0.005143	4.358475	0.005097	2.605975
Interaction	0.002548	4	0.000637	0.539831	0.70732	2.605975
Within	0.0472	40	0.00118			
Total	0.071202	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device’s and the industrial grade device’s data

Results Interpretation: Ohio River TDS Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter
- Since most of the Standard Error bars are not overlapping, there **will** probably be significant variation between the two groups

Two-Factor ANOVA - Ohio River TDS Levels

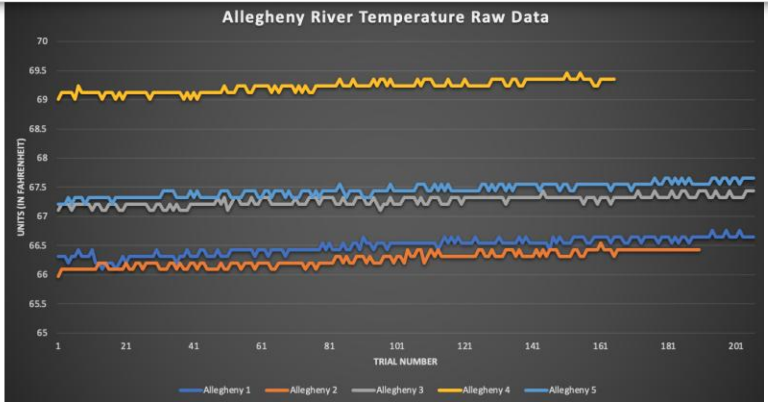
Analytical Approach

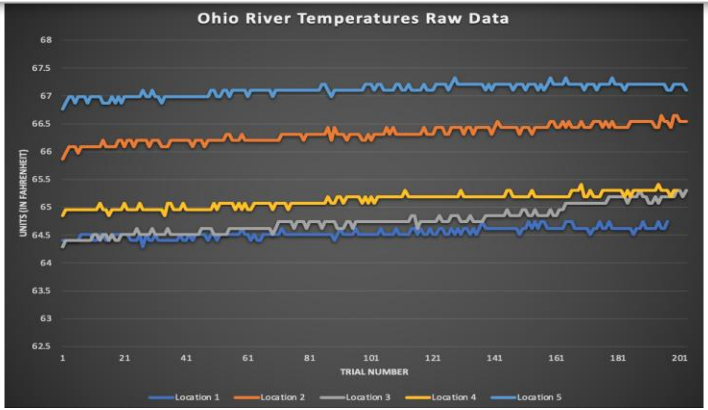
Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	618.8	575.6	614.8	562.4	559.2	2930.8
Average	123.76	115.12	122.96	112.48	111.84	117.232
Variance	161.728	424.992	87.328	178.832	71.968	181.5456
Treatment						
Count	5	5	5	5	5	25
Sum	618.9716	679.3959	654.2926	620.2297	602.2777	3175.168
Average	123.7943	135.8792	130.8585	124.0459	120.4555	127.0067
Variance	0.717163	0.014361	16.63571	2.276602	0.042958	35.6896
Total						
Count	10	10	10	10	10	
Sum	1237.772	1254.996	1269.093	1182.63	1161.478	
Average	123.7772	125.4996	126.9093	118.263	116.1478	
Variance	72.19818	308.5984	63.53568	117.6514	52.62363	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	1194.31	1	1194.31	12.64443	0.000986	4.084746
Columns	876.4901	4	219.1225	2.319899	0.073455	2.605975
Interaction	559.0155	4	139.7539	1.479605	0.226504	2.605975
Within	3778.139	40	94.45348			
Total	6407.955	49				

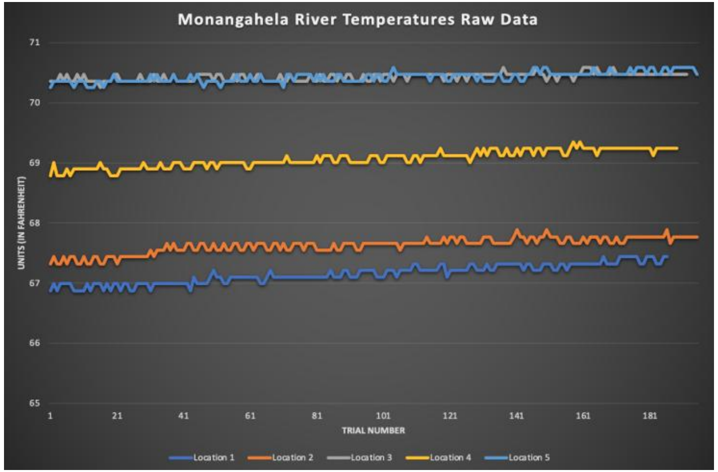
- Since the p-value is less than 0.05 and the f-value is greater than the f-crit, there was variation between my device's and the industrial grade device's data

Results: Temperature Levels of 3 Rivers

Analytical Approach







- Since the temperature of the water samples rose to room temperature when I brought them in my house, I couldn't use temperature as a parameter in this project

- The line graphs show all 200 trials of each location
- Each line represents a different location

Summary Results based on Two-Factor ANOVA

Analytical Approach

Water Quality Measurement	River	Control Group vs Experimental Group			Does experimental group deviate from control group?
		Standard error bars overlapping (Y/N)?	p Value	f-crit	
pH	Ohio	Yes	> 0.05	> f-value	No
	Monangahela	Yes	> 0.05	> f-value	No
	Allegheny	Yes	> 0.05	> f-value	No
TDS	Ohio	No	< 0.05	< f-value	Yes
	Monangahela	No	< 0.05	< f-value	Yes
	Allegheny	No	< 0.05	< f-value	Yes
Turbidity	Ohio	Yes	> 0.05	> f-value	No
	Monangahela	Yes	> 0.05	> f-value	No
	Allegheny	Yes	> 0.05	> f-value	No

TDS levels deviated from the Control group leaving for me to test my device further for TDS. Next step was to use a different Industry grade device as the control group and/or use a different TDS sensor for Arduino and perform the testing again

Conclusion: Final Comparison: *Potamoi is multi-functional, shows historical data, has a simplistic interface, and is cost effective, unlike many currently-available devices.*

	Potamoi	Current Devices on the Market

Functionality

Potamoi

- App-Driven
- 4 parameters
- Portable
- Strong Data Storage
- Real-Time View
- Strong Location ID
- Strong Date & Time Logging

Current Devices on the Market

- Not App-Driven
- < 4 Parameters
- Portable
- Limited Data Storage
- Real-Time View
- Limited Location ID
- Limited Date & Time Logging

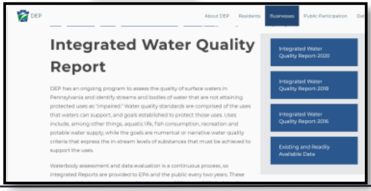
Data Retention

Potamoi

Hide fields · Filter · Group · Sort · Color · Share view

	Trial Numb...	River Name	Location	Temper...	pH	TDS	Turbidity
14	Trial 14	OH	Location 1	64.51	7.64	122	0.70
15	Trial 15	OH	Location 1	64.40	7.66	120	0.62
16	Trial 16	OH	Location 1	64.40	7.66	124	0.70
17	Trial 17	OH	Location 1	64.51	7.64	125	0.63
18	Trial 18	OH	Location 1	64.51	7.84	124	0.68
19	Trial 19	OH	Location 1	64.51	7.62	120	0.63
20	Trial 20	OH	Location 1	64.51	7.62	122	0.71
21	Trial 21	OH	Location 1	64.51	7.66	124	0.72
22	Trial 22	OH	Location 1	64.51	7.62	124	0.63
23	Trial 23	OH	Location 1	64.40	7.62	120	0.72

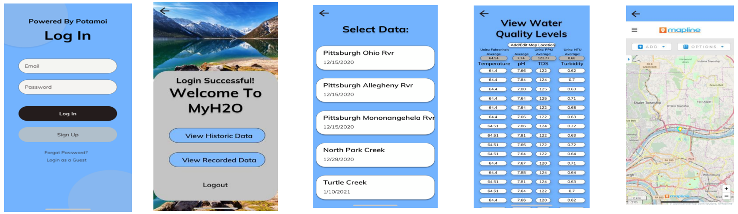
Current Devices on the Market



Ref: Home (pa.gov)

User Interface

Potamoi



Current Devices on the Market

Cost

Potamoi

- **$90**

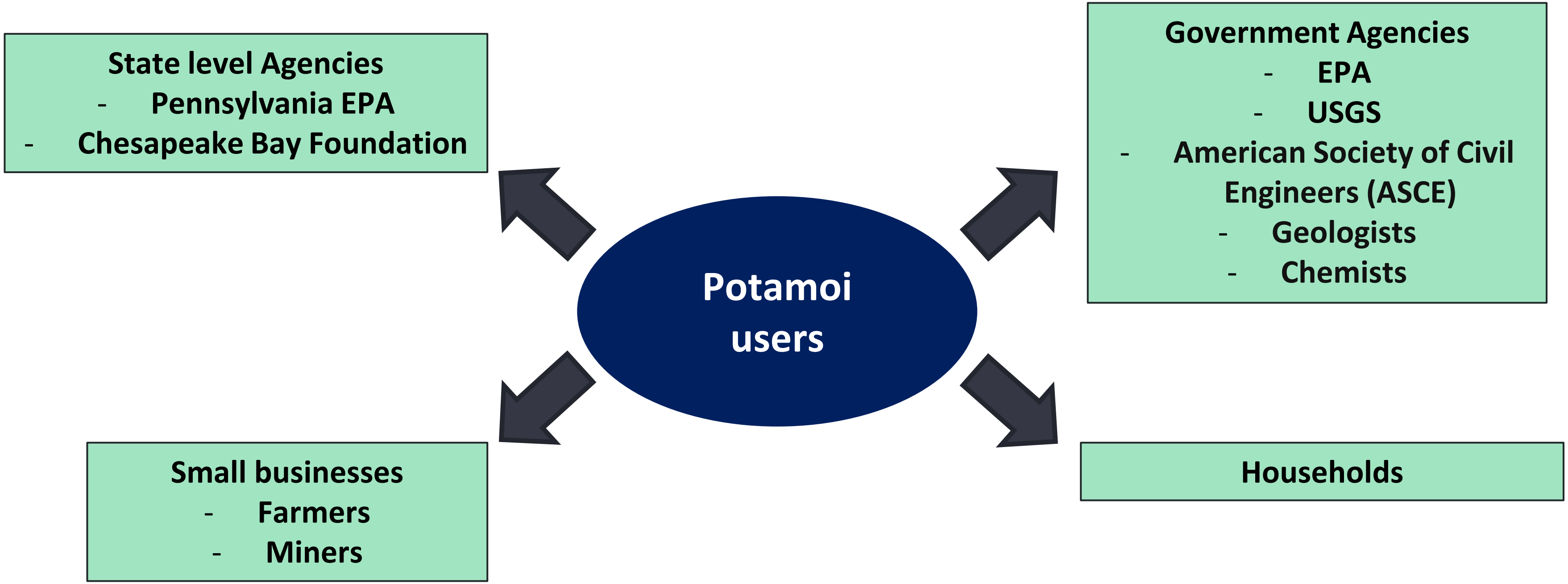
PC : Student

Current Devices on the Market

- (Household) - $10 - $100 (un-reliable)
- (Small Businesses) - $125 - $1500
- (Corporate): approx. $2000 - $3500

PC : Amazon.com

Conclusion: Who all will benefit from “Potamoi”?



Conclusion cont.

- Engineering Goal #1: Historical Data
  - Data was exported to the Airtable as well as saved in SD card (a way to transfer historical data)
  - Data was also transmitted to my app, “MyH_2O” using Airtable APIs offered by Airtable
  - “MyH_2O” displayed the data in an easy-to-read format and also allows historical data to be retained

- Engineering Goal # 2: Real-time, simple user interface
  - Developed two solutions, LCD display for real time reading and created an easy to develop mobile app (The data can be retrieved either using mobile app or browser)
  - “MyH_2O” Mobile App is very easy to use and displays the water quality data in up to ten minutes.
  - The app also was able to record the location of where the data was taken from via a tool called Mapline.

- Engineering Goal #3 : Minimize Cost
  - The cost of my device was less than $100 whereas the cost of the industrial-grade device I used as the control and many other water quality measuring devices were $20 - $4000; low-cost devices are unreliable for users.

Conclusion cont.

- My Water Quality Measurement device (Potamoi) was proved to be accurate based on the comparisons against the industrial-grade device, the ANOVA tests, and the error bars.
- Since there was only significant variation in the TDS results, it is likely that my sensor wasn't calibrated properly
- The Bluetooth Module was able to connect to Blynk, which is an app especially for controlling an Arduino, but it wasn't able control all four sensors simultaneously
- When I brought the temperature samples into my house, the temperature rose to room temperature, so I couldn't use temperature as a parameter, but I still recorded the data "Potamoi" received from the temperature sensor
- I successfully incorporated a battery pack into "Potamoi" so that it didn't have to be attached to a computer and could be taken anywhere

Limitations

- Sensors needed to be calibrated once in a while
- Received errors while using the Arduino IDE software for no apparent reason. The project took a longer time than I expected to complete. Therefore, I couldn't incorporate all the functions I wanted to include
- The browser based software I used to build "MyH_2O" couldn't display the data in a graphical form
- Temperature readings were not the same as when collected from the rivers because the water rose to room temperature as soon as it entered my house

Extensions / Next Steps

- Make the device further portable by using a smaller microcontroller (Arduino Nano, Arduino Micro)
- Include more parameters for water quality testing (dissolved oxygen, electrical conductivity)
- Use a different TDS sensor to identify which device had the deviation (my Experimental Group Potamoi or the Control Group Device)
- Implement graphical forms of the data being presented in “MyH_2O“
- Make an option in “MyH_2O“ for the users to subscribe to a river/water location. When that location’s water quality data changes or new data is uploaded into “MyH_2O”, then the user gets an email alert from “MyH_2O“
- Find an automated method to collect water samples from various depths of the water for more variability (robot, drone etc.)

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Appendix

Appendix

1. My Arduino Code
2. My daily Engineering Log kept past three months
3. Pictures of Design, Build and Test
4. Graphs and Statistical Analysis of each water quality parameter on the Rivers

1. Arduino Code

Arduino Code

```
/**************************************************************************
 * Purpose: The program has some key groups: The Setup, Loop, and Error
 * First, the Setup calibrates the 4 sensors and LCD to perform the testing and creates
the SD card file
 *  The Loop programs the data logging shield to store data from the sensors
 * in the SD Card and prints the data on the Arduino Serial Monitor
*  The Error module captures any errors and handles them
 * Creator: Student
 ************************************************************************ */

#include <RTClib.h>
#include "SD.h"
#include <Wire.h>
#include <OneWire.h>
#include <GravityTDS.h>
#include <EEPROM.h>
#include <DallasTemperature.h>
#include<LiquidCrystal.h>
#define Offset 0.00          //deviation compensate for pH
#define PH A2
#define ONE_WIRE_BUS A0
#define TDS A1
#define Pushbutton 10
#define Turbidity A3
#define Backlight 11
#define LOG_INTERVAL  1000 // mills between entries
#define ECHO_TO_SERIAL   1 // echo data to serial port
#define WAIT_TO_START    0 // Wait for serial input in setup()
#define SYNC_INTERVAL 1000 // mills between calls to flush() - to write data to the
card
```

```
unsigned long int avgValue;    //Store the average value of pH sensor
feedback

const int RS = 7, E = 6, D4 = 4, D5 = 5, D6 = 8, D7 = 9;
const int chipSelect = 10;      // for the data logging shield, we use
digital pin 10 for the SD cs line
int buttonVal = 1;

char daysOfTheWeek[7][12] = {"Sunday", "Monday", "Tuesday",
"Wednesday", "Thursday", "Friday", "Saturday"};
GravityTDS gravityTds;
LiquidCrystal lcd(RS, E, D4, D5, D6, D7);
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
DateTime now;
float Celcius=0;
float Fahrenheit=0;
float temperature = 25;
float tdsValue=0;
float volt;
float ntu;
uint32_t syncTime = 0; // time of last sync()
RTC_DS1307 RTC; // define the Real Time Clock object
File logfile;   // the logging file
```

Arduino Code

```
void error(char *str)
{
  Serial.print("error: ");
  Serial.println(str);

  while(1);
}

void setup()
{
  Serial.begin(9600);
  Wire.begin();
  RTC.begin();
  Serial.println();
  //RTC.adjust(DateTime(21,3,6,9,59,00));
  #if WAIT_TO_START
    Serial.println("Type any character to start");
    while (!Serial.available());
  #endif //WAIT_TO_START    // initialize the SD card
  Serial.print("Initializing SD card...");
  sensors.begin();
  gravityTds.setPin(TDS);
  gravityTds.setAref(5.0); //reference voltage on ADC, default 5.0V on
Arduino UNO
  gravityTds.setAdcRange(1024); //1024 for 10bit ADC;4096 for 12bit ADC
  gravityTds.begin(); //initialization

  lcd.begin(20, 4);          //Sets up the LCD's number of columns and rows
  lcd.clear();               //Clears any existing data on LCD
```

```
pinMode(Pushbutton, INPUT_PULLUP);
  pinMode(ONE_WIRE_BUS, INPUT);      //Temperature sensor data pin
  pinMode(TDS, INPUT);       //TDS sensor data pin
  pinMode(PH, INPUT);        //pH sensor data pin
  pinMode(10, OUTPUT);       // make sure that the default chip select pin is set
to output, even if you don't use it:
// see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    Serial.println("");
    Serial.println("Date & Time                Temp (In Fahrenheit)        pH
TDS (In PPM)      Turbidity (In NTU)");
    return;
  }
  Serial.println("card initialized.");

  // create a new file
  char filename[] = "WQDATA00.txt";
  for (uint8_t i = 0; i < 100; i++) {
    filename[6] = i/10 + '0';
    filename[7] = i%10 + '0';
    if (! SD.exists(filename)) {
      // only open a new file if it doesn't exist
      logfile = SD.open(filename, FILE_WRITE);
      break;  // leave the loop!
    }
  }
```

Arduino Code

```
 if (! logfile) {
    error("couldnt create file");
  }
  Serial.print("Logging to: ");
  Serial.println(filename);

Wire.begin();
  if (!RTC.begin()) {
    logfile.println("RTC failed");
#if ECHO_TO_SERIAL
    Serial.println("RTC failed");
#endif
  }
  logfile.println("Date & Time                    Temp (In Fahrenheit)         pH
TDS (In PPM)      Turbidity (In NTU)");
#if ECHO_TO_SERIAL
  Serial.println("Date & Time                    Temp (In Fahrenheit)         pH
TDS (In PPM)      Turbidity (In NTU)");
#endif ECHO_TO_SERIAL
}
void loop()
{
   now = RTC.now();

  // delay for the amount of time we want between readings
  delay((LOG_INTERVAL -1) - (millis() % LOG_INTERVAL));
  RTC.now();
  logfile.print(now.year(), DEC);
  logfile.print("/");
```

```
logfile.print(now.month(), DEC);
logfile.print("/");
  logfile.print(now.day(), DEC);
  logfile.print(" (");
  logfile.print(daysOfTheWeek[now.dayOfTheWeek()]);
  logfile.print(") ");
  logfile.print(now.hour(), DEC);
  logfile.print(":");
  logfile.print(now.minute(), DEC);
  logfile.print(":");
  logfile.print(now.second(), DEC);
  logfile.print("           ");
#if ECHO_TO_SERIAL
  RTC.now();
  Serial.print(now.year(), DEC);
  Serial.print("/");
  Serial.print(now.month(), DEC);
  Serial.print("/");
  Serial.print(now.day(), DEC);
  Serial.print(" (");
  Serial.print(daysOfTheWeek[now.dayOfTheWeek()]);
  Serial.print(") ");
  Serial.print(now.hour(), DEC);
  Serial.print(":");
  Serial.print(now.minute(), DEC);
  Serial.print(":");
  Serial.print(now.second(), DEC);
  Serial.print("           ");
#endif //ECHO_TO_SERIAL
```

Arduino Code

```
sensors.requestTemperatures();
  Celcius=sensors.getTempCByIndex(0);
  Fahrenheit=sensors.toFahrenheit(Celcius);
  lcd.setCursor(0,2);        //Sets cursor to point (0,4)
  lcd.print("Temperature: "); // Prints Temperature to LCD
  lcd.print(Fahrenheit);//Prints value of Temperature sensor to LCD
  delay(200);

  float phValue=(float)analogRead(PH)*5.0/1024; //convert the analog into
millivolt
  phValue=3.5*phValue+Offset;                  //convert the millivolt into pH value
  lcd.setCursor(0,0);                          //Sets cursor to point (0,0)
  lcd.print("pH Level: ");                     //Prints pH Level: to LCD
  lcd.print(phValue);                          //Prints value of pH sensor to LCD
  delay(200);

  gravityTds.update(); //calculation done here from gravity library
  tdsValue = gravityTds.getTdsValue(); // then get the TDS value
  lcd.setCursor(0,1);        //Sets cursor to point (0,2)
  lcd.print("TDS Level: ");   //Prints TDS Level: to LCD
  lcd.print(tdsValue,0); //Prints value of TDS sensor to LCD
  lcd.print("ppm");
  delay(200);

  volt = ((float)analogRead(Turbidity)/1023)*7.5;
  ntu = volt - 4;
  lcd.setCursor(0,3);
  lcd.print("Turbidity: ");
  lcd.print(ntu);
  delay(200);
```

```
 logfile.print(Fahrenheit);
  logfile.print("                ");
  logfile.print(phValue);
  logfile.print("              ");
  logfile.print(tdsValue, 0);
  logfile.print("              ");
  logfile.print(ntu);
#if ECHO_TO_SERIAL
  Serial.print(Fahrenheit);
  Serial.print("                ");
  Serial.print(phValue);
  Serial.print("              ");
  Serial.print(tdsValue, 0);
  Serial.print("              ");
  Serial.println(ntu);
#endif //ECHO_TO_SERIAL

logfile.println();
#if ECHO_TO_SERIAL
#endif // ECHO_TO_SERIAL
if ((millis() - syncTime) < SYNC_INTERVAL) return;
  syncTime = millis();
logfile.flush();
}
```

2. Daily Engineering Log

Daily Research Log - 2021

Date	Task	Resolution
1/3	Began learning app development and Arduino basics by reading and printing out online resources	
1/4 to 1/6	Ordered parts for the device (i.e. four sensors, potentiometer, soldering iron, data-logging shield, and LCD display) from Amazon.com	
1/9	I soldered the header pins onto the LCD display to be able to fit into breadboard	
1/10	I wired the 4 sensors, (Temperature, pH, TDS and Turbidity) in to the Arduino Uno	
1/11-1/13	I started writing the code in Arduino IDE to get these sensors working to display data; read books and looked up questions on different communities such as Arduino.com and Adafruit.com to learn how to program each sensor	
1/14	LCD Display was connected and added the code to get it to display real-time data	
1/14-1/20	Worked on refining the program for sensors while identifying the correct formula for each sensor to display the right units; This was the first time I read about PuTTY and got my sensor data to post on to PuTTY screen; PuTTY allows me to write the data I got from the Arduino into a .txt file	
1/21-1/23	Data-logging shield programming was very challenging. It took a lot of extra after-school time to find the right code that would accomplish what I wanted	Data-logging shield was not working. Debugging postponed to tomorrow

Daily Research Log – 2021 cont.

Date	Task	Resolution
1/24-1/25	I read further and looked into the Arduino.com community and found that others were having same problem as myself. To solve this problem, I added a different logfile command that was compatible with my computer to be able to write the data to the SD card. The date and time were still showing 1/1/2000, though.	
1/26-1/28	I implemented another app, Blynk, that would show what was being displayed on the LCD display via Bluetooth using a Bluetooth module.	Blynk wasn't getting a signal from my Arduino via the Bluetooth module. I decided to leave it aside and move on with the key tasks.
1/29	To make sure all of the sensors were working, I tested tap water	All results were normal so I was ready to get water samples
1/30	I went to Point State Park to collect the water samples. I collected water from five locations along each of three rivers: Allegheny, Ohio, and Monongahela	I collected 15 samples of water
1/31	I started uploading my sketch (program/code in Arduino IDE) with the first water sample, but I was getting this error: "avrdude: stk500_getsync(): not in sync: resp=0x00"	Looked through Arduino forums and found that many people do not know what to do when they encounter this problem
2/1	As I was working on a MacBook, one person on the forum advised me to download the "https://brew.sh/" package	Even after downloading this, I still got the error
2/7	After almost a week playing around with different installers to get rid of the "Sketch upload" error, I ran the program on a Windows computer instead of a Mac.	It worked without any errors.

Daily Research Log – 2021 cont.

Date	Task	Resolution
2/10	I worked on the data-logger shield and got the date and time to display accurately	I got it to work because I installed a different library as I had a different RTC clock chip than other data-logging shields.
2/12	Was able to get the Blynk app working with “Potamoi”	
2/14	When the Blynk code was merged with main code, the LCD stopped working	I thought this was because there were too many commands in the program, and the Arduino couldn’t handle all of them
2/16	Blynk app provided very limited information via the Bluetooth module	
2/17	Back to my app development - I got Bravo Studio to list all of my data using Airtable	I decided NOT to use the Blynk module as my own app provides more information
2/21	Complete all 200 trials for each of the 15 locations, and logged them into an SD card and to PuTTY	
2/22	After reading a Bravo forum, I came to know a website called Integromat that was able to create workflow and conditional logic statements via webhooks	
2/23	I Integrated a top bar into my data display page in my app so that the header would stay fixed when scrolling	
2/24	I created a text bar with the averages in the top bar for each parameter in my app	
2/28	I created the design for my 3d printed case for “Potamoi”	

Daily Research Log – 2021 cont.

Date	Task	Resolution
3/1	Sent the box design (hand drew and then drew in Tinkercad) to one of my teachers and answered any questions he had about it before he started printing it.	
3/3	After logging into Figma to update my app design again, I received the following error: "403 Forbidden from the operation" when importing Figma file to Bravo Studio	
3/3	Posted error message to Bravo Studio community	No response
3/4	Resolved Figma error on my own by deleting browser cache and re-logging in to the website	
3/5	Collected the box for Potamoi from my teacher	
3/6	Worked on conditional logic statements in Integromat to get data from three different tables from one “Select Data” screen in my app.	
3/8	As I was pressed for time and Integromat was still not working, I decided to leave it and work on my app	I decided not to use integromat for this time.
3/9	Added a location screen to my app using the Bravo Studio web view so users can view the location of where they took their data from	
3/10	Worked on research report for judges	App was finally completed
3/11 to 3/14	Worked on PowerPoint for fair day presentation	
3/14	Uploaded work to the PRSEF Zfairs site	Finally finished after 3 months of work!

2. Supporting documents on Procedural Plan

“Potamoi” Design Steps

Procedural Plan

- I sketched the device design using TinkerCad (see slides #19 - 22)
- I purchased and wired the 4 sensors, a 20x4 LCD display, a data logging shield, and a Bluetooth moduleinot the
- I soldered header pins onto the LCD display
- I wired the 4 sensors, LCD display, and Bluetooth module into the breadboard and hooked them up to the Arduino Uno
- I learned the basics of Arduino coding from library books and online resources
- I downloaded Arduino IDE from Arduino.com (and the necessary libraries from GitHub)
- I created the code for the 4 sensors in the Arduino IDE software
- After numerous failures, I created a successful code for the data logging shield
- I paired the Bluetooth module with Blynk, an app especially designed for controlling an Arduino, to be able to display the water quality data in real-time
- I tested the device many times with my household tap water to make sure my device was reliable

“Potamoi” Design Steps cont.

Procedural Plan

- I went to Point State Park to collect five water samples from five different locations in each of the three main rivers: the Ohio, Monongahela, and the Allegheny
- I used a prong-shaped tool connected to a bucket to collect the water and transferred the samples to clean plastic containers for testing. Altogether I collected 15 different water samples from the various locations
- I submerged all four of the sensor’s probes into each of the water samples for 10 minutes. Since I was receiving data every two seconds, I got about 200 - 300 data points for each sample
- I wasn’t able to use the Bluetooth module with Blynk since the module couldn’t connect to all four of my sensors simultaneously
- Using the Data-logging shield, I logged all of the data to an SD card
- I used an application called PuTTY to transfer all of the data to a .txt file (The difference between this and the Data logging shield is that PuTTY shows the data being logged on the computer screen whereas the Data logging shield just logs the data)
- I transmitted the data from the .txt file to a website called Airtable that is similar to Excel to be able to send my data directly to my app, “MyH_2O”

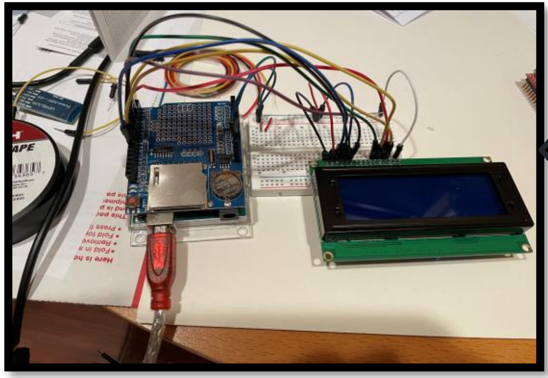
“Potamoi” Design and Build

Procedural Plan

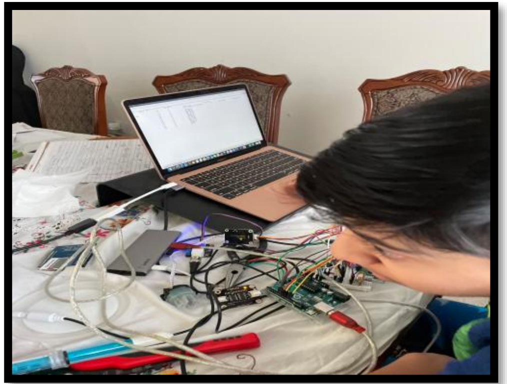
Collecting water

Water samples

Soldering the LCD display



Wiring the Data Logging Shield (left to the LCD in the picture)

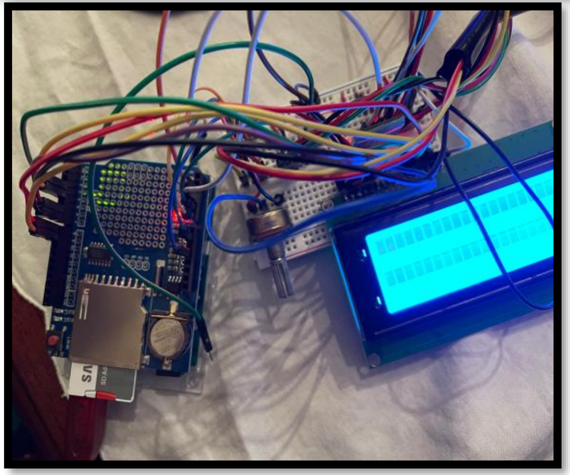


Connecting the four sensors

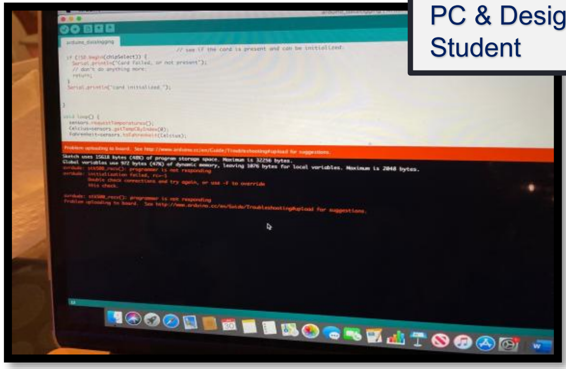
PC & Designed by: Student

“Potamoi” Design and Build cont.

Procedural Plan

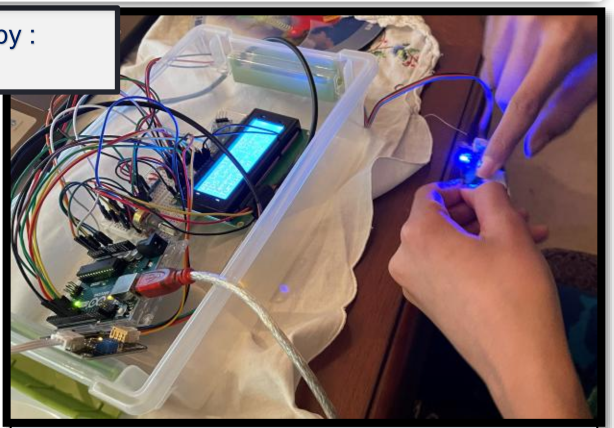


Data logging shield (SD card inserted) and LCD screen

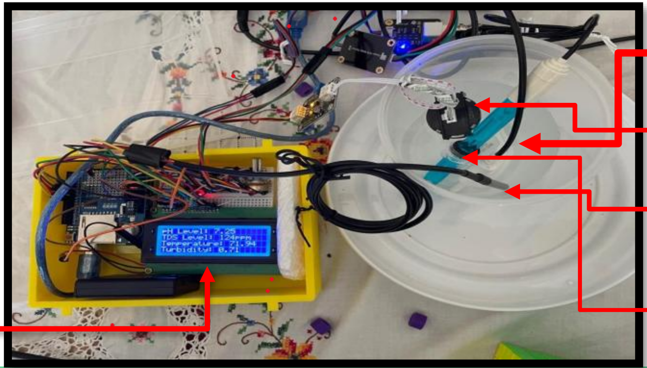


Errors that I had to debug

PC & Designed by : Student



Calibrating the turbidity Sensor



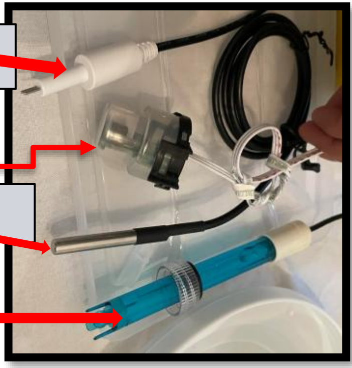
LCD showing one trial data – pH, Temperature, TDS, and Turbidity Values

TDS Sensor

Turbidity Sensor

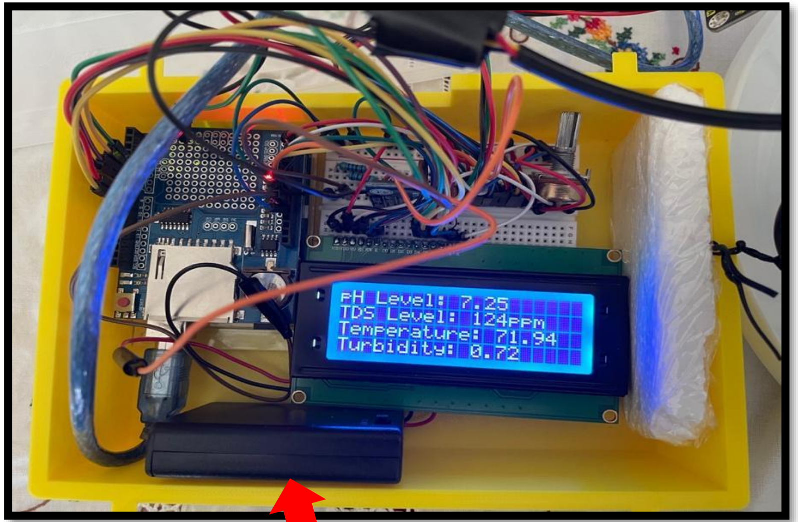
Temperature Sensor

pH Sensor

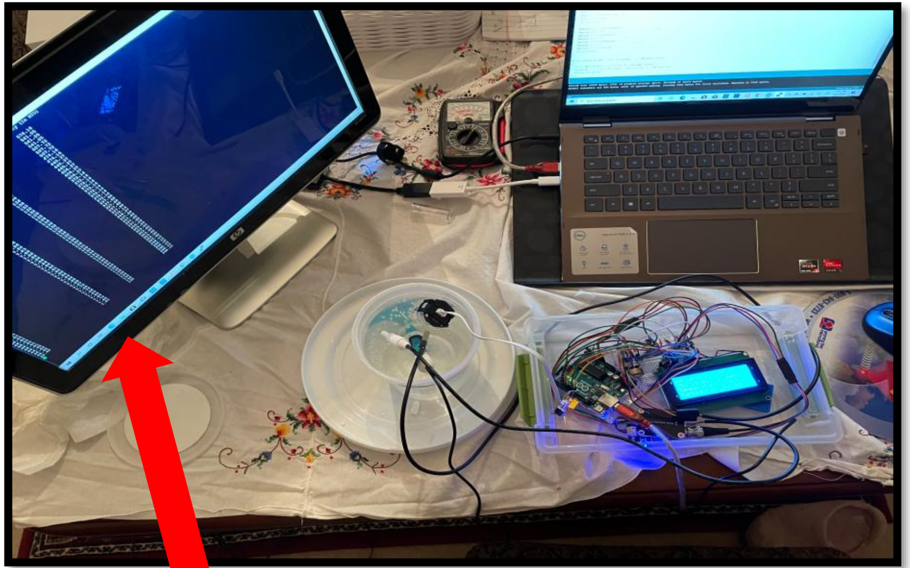


“Potamoi” During Testing

Procedural Plan



Battery pack to make “Potamoi” wireless when using in the field



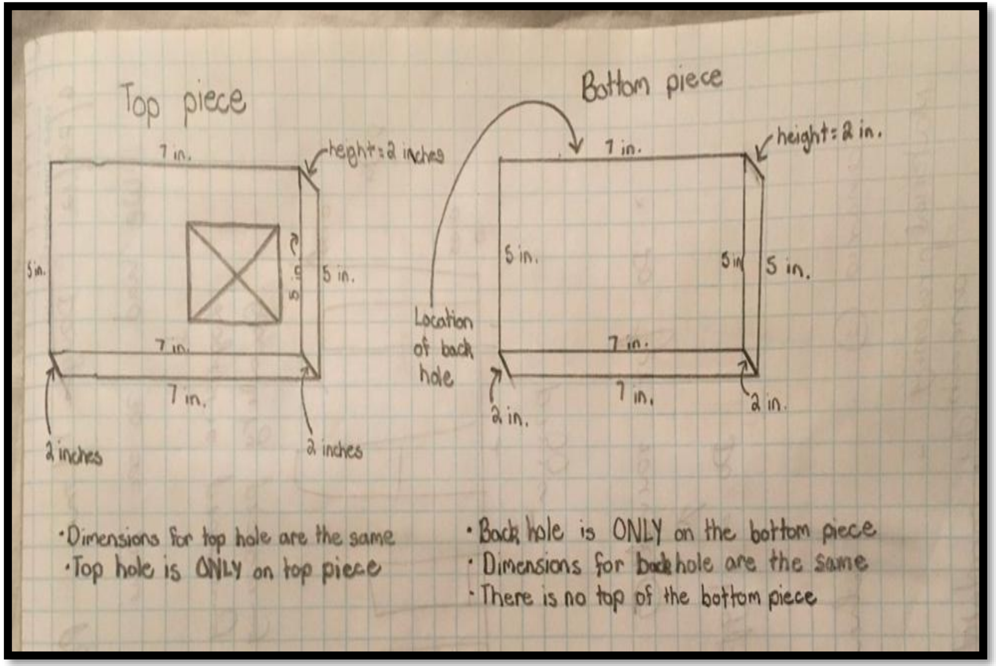
Data on the screen via PuTTy

PC & Designed by : Student

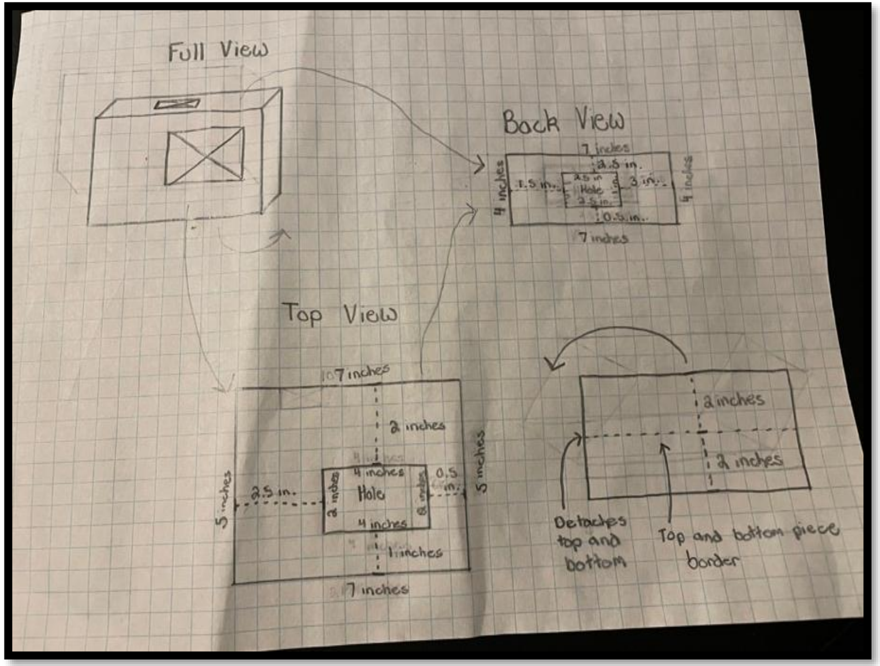
“Potamoi” Box – Sketch/Blueprint Design

Procedural Plan

PC & drawn by: Student



Top & bottom piece view I created for 3D-printed box

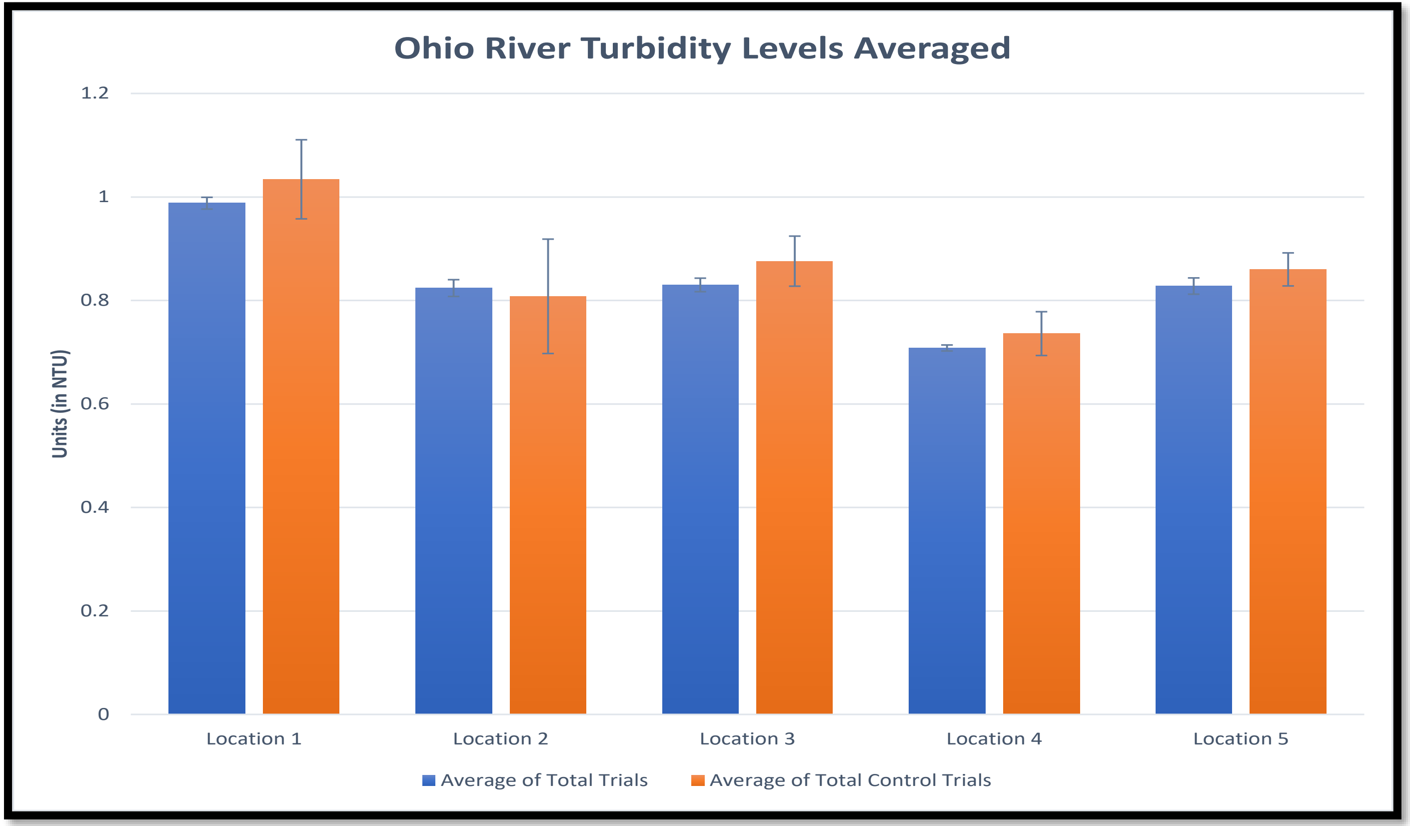


Front and full view

4. Supporting Graphs and Statistical Analysis for the rest of the river locations

Results Interpretation: Ohio River Turbidity Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter
- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Ohio River Turbidity Levels

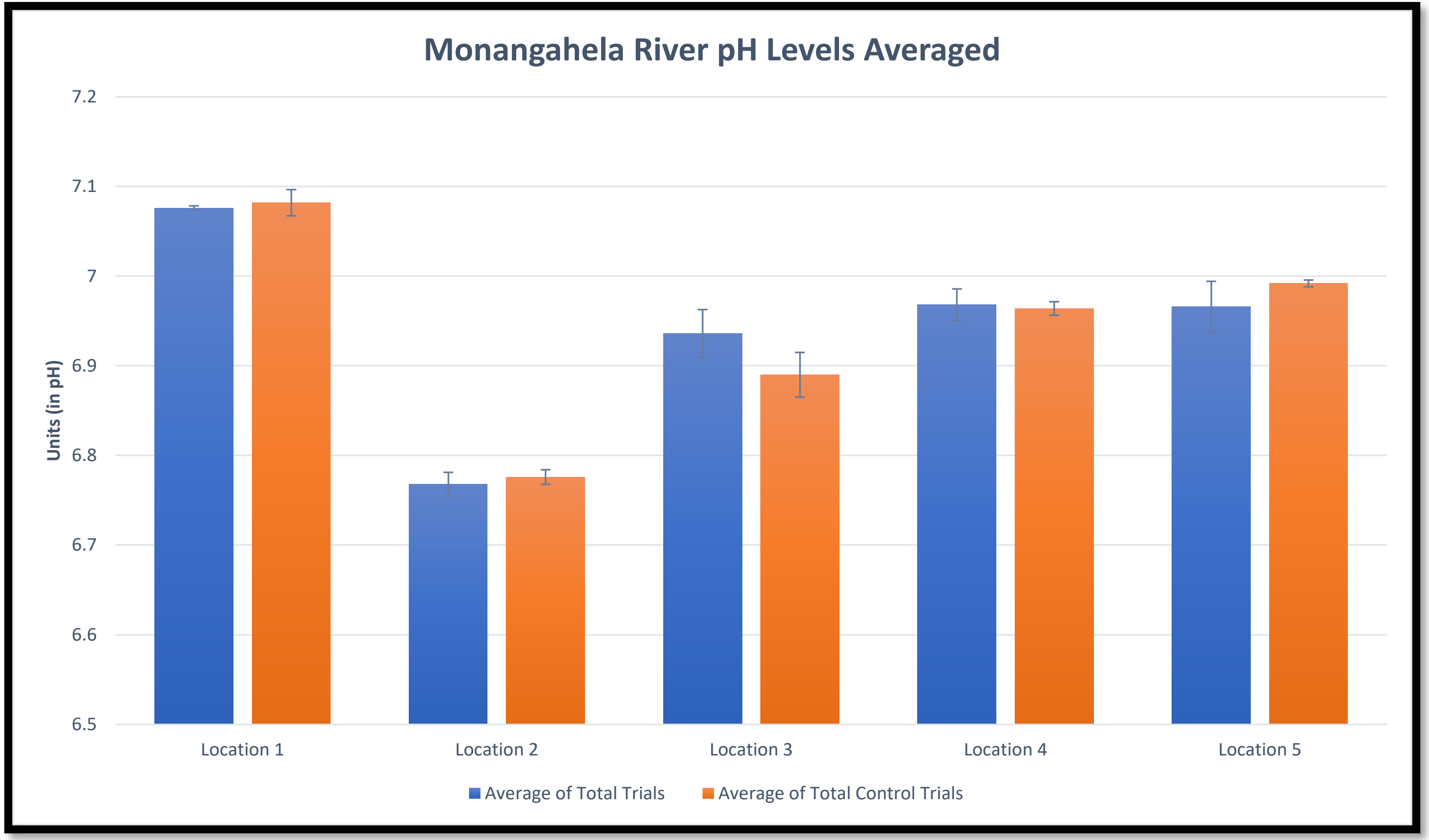
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	5.35	4.04	4.38	3.68	4.3	21.75
Average	1.07	0.808	0.876	0.736	0.86	0.87
Variance	0.0292	0.06112	0.01173	0.00893	0.00505	0.032242
Treatment						
Count	5	5	5	5	5	25
Sum	4.94	4.12	4.15	3.54	4.14	20.89
Average	0.988	0.824	0.83	0.708	0.828	0.8356
Variance	0.00067	0.00128	0.00085	0.00017	0.00122	0.008976
Total						
Count	10	10	10	10	10	
Sum	10.29	8.16	8.53	7.22	8.44	
Average	1.029	0.816	0.853	0.722	0.844	
Variance	0.015143	0.027804	0.006179	0.004262	0.003071	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.014792	1	0.014792	1.230411	0.273952	4.084746
Columns	0.495868	4	0.123967	10.31168	7.81E-06	2.605975
Interaction	0.012468	4	0.003117	0.259275	0.90226	2.605975
Within	0.48088	40	0.012022			
Total	1.004008	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device's and the industrial grade device's data

Results Interpretation: Monangahela River pH Levels

Analytical Approach



BLUE bar – “Potamoi” Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter

- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Monongahela River pH Levels

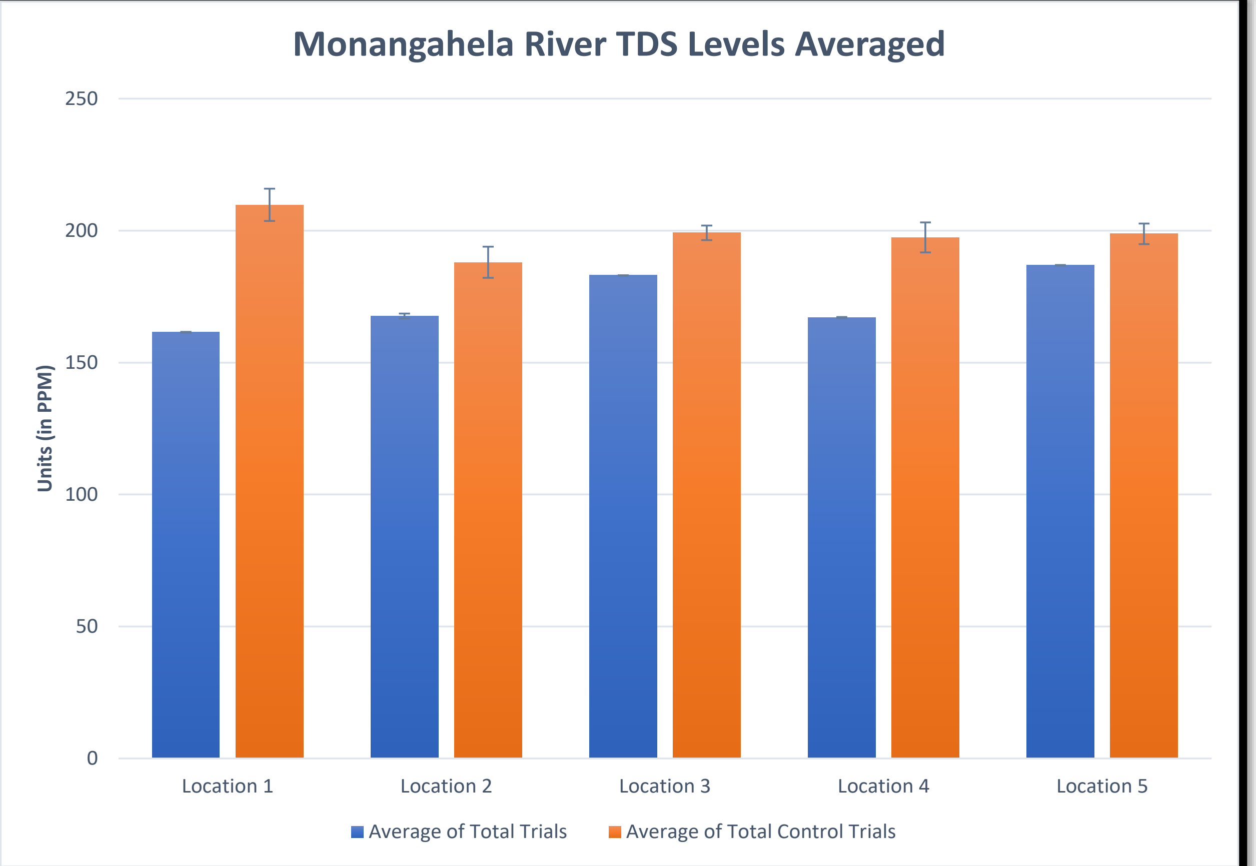
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	35.41	33.88	34.45	34.82	34.96	173.52
Average	7.082	6.776	6.89	6.964	6.992	6.9408
Variance	0.00107	0.00033	0.0031	0.00028	7E-05	0.011816
Treatment						
Count	5	5	5	5	5	25
Sum	35.38	33.84	34.68	34.84	34.83	173.57
Average	7.076	6.768	6.936	6.968	6.966	6.9428
Variance	3E-05	0.00087	0.00363	0.00157	0.00398	0.011996
Total						
Count	10	10	10	10	10	
Sum	70.79	67.72	69.13	69.66	69.79	
Average	7.079	6.772	6.913	6.966	6.979	
Variance	0.000499	0.000551	0.003579	0.000827	0.001988	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	5E-05	1	5E-05	0.03349	0.855721	4.084746
Columns	0.504548	4	0.126137	84.4856	5.87E-19	2.605975
Interaction	0.00722	4	0.001805	1.208975	0.32209	2.605975
Within	0.05972	40	0.001493			
Total	0.571538	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device’s and the industrial grade device’s data

Results Interpretation: Monangahela River TDS Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter

- Since most of the Standard Error bars are not overlapping, there **will** probably be significant variation between the two groups

Two-Factor ANOVA - Monongahela River TDS Levels

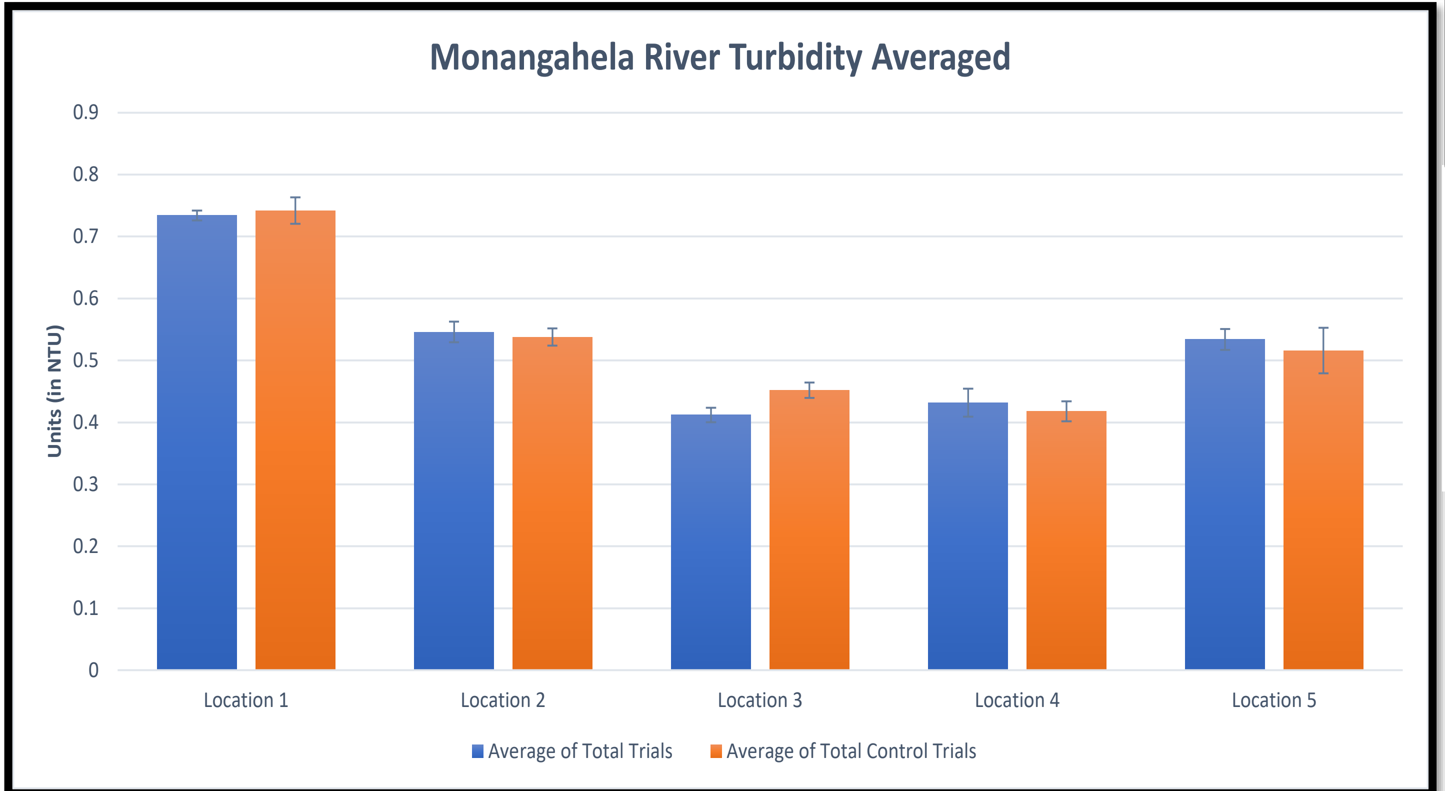
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	1048.8	940	996	987.2	994	4966
Average	209.76	188	199.2	197.44	198.8	198.64
Variance	188.208	175.6	38.64	161.808	76.24	156.4667
Treatment						
Count	5	5	5	5	5	25
Sum	807.4962	838.3063	915.2519	835.3038	934.4962	4330.854
Average	161.4992	167.6613	183.0504	167.0608	186.8992	173.2342
Variance	0.12433	3.792117	0.016587	0.18195	0.041037	102.7696
Total						
Count	10	10	10	10	10	
Sum	1856.296	1778.306	1911.252	1822.504	1928.496	
Average	185.6296	177.8306	191.1252	182.2504	192.8496	
Variance	730.676	194.6367	89.62795	328.356	73.24388	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	8068.201	1	8068.201	125.1559	6.89E-14	4.084746
Columns	1541.005	4	385.2513	5.976113	0.000723	2.605975
Interaction	2102.056	4	525.514	8.151902	6.62E-05	2.605975
Within	2578.608	40	64.4652			
Total	14289.87	49				

- Since the p-value is less than 0.05 and the f-value is greater than the f-crit, there was variation between my device's and the industrial grade device's data

Results Interpretation: Monangahela River Turbidity Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter
- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Monongahela River Turbidity Levels

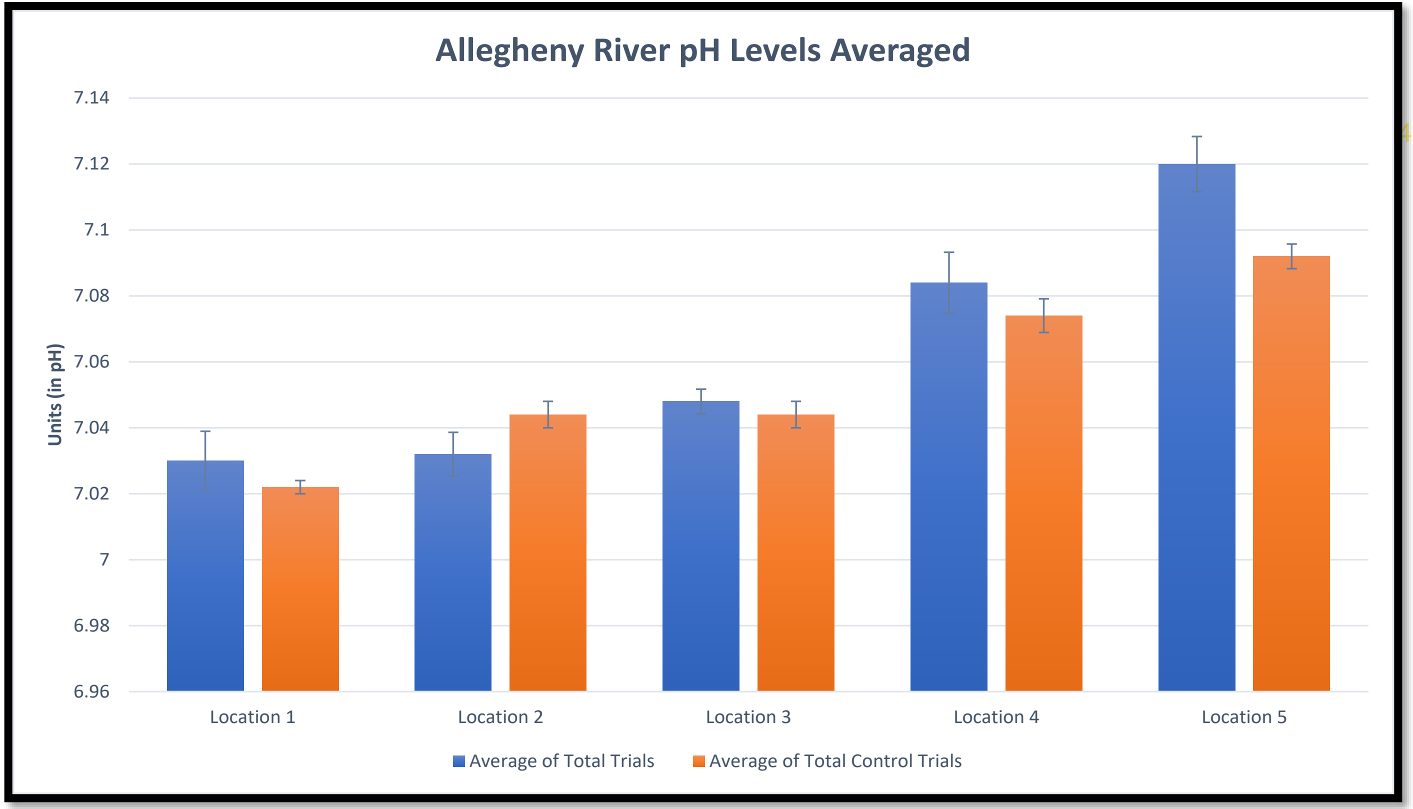
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	3.71	2.69	2.26	2.09	2.58	13.33
Average	0.742	0.538	0.452	0.418	0.516	0.5332
Variance	0.00227	0.00097	0.00077	0.00127	0.00673	0.015289
Treatment						
Count	5	5	5	5	5	25
Sum	3.67	2.73	2.06	2.16	2.67	13.29
Average	0.734	0.546	0.412	0.432	0.534	0.5316
Variance	0.00033	0.00138	0.00067	0.00257	0.00143	0.014689
Total						
Count	10	10	10	10	10	
Sum	7.38	5.42	4.32	4.25	5.25	
Average	0.738	0.542	0.432	0.425	0.525	
Variance	0.001173	0.001062	0.001084	0.001761	0.003717	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3.2E-05	1	3.2E-05	0.017401	0.895715	4.084746
Columns	0.640332	4	0.160083	87.04894	3.45E-19	2.605975
Interaction	0.005588	4	0.001397	0.759652	0.557724	2.605975
Within	0.07356	40	0.001839			
Total	0.719512	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device's and the industrial grade device's data

Results Interpretation: Allegheny River pH Levels

Analytical Approach



BLUE bar – “Potamoi” Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter

- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Allegheny River pH Levels

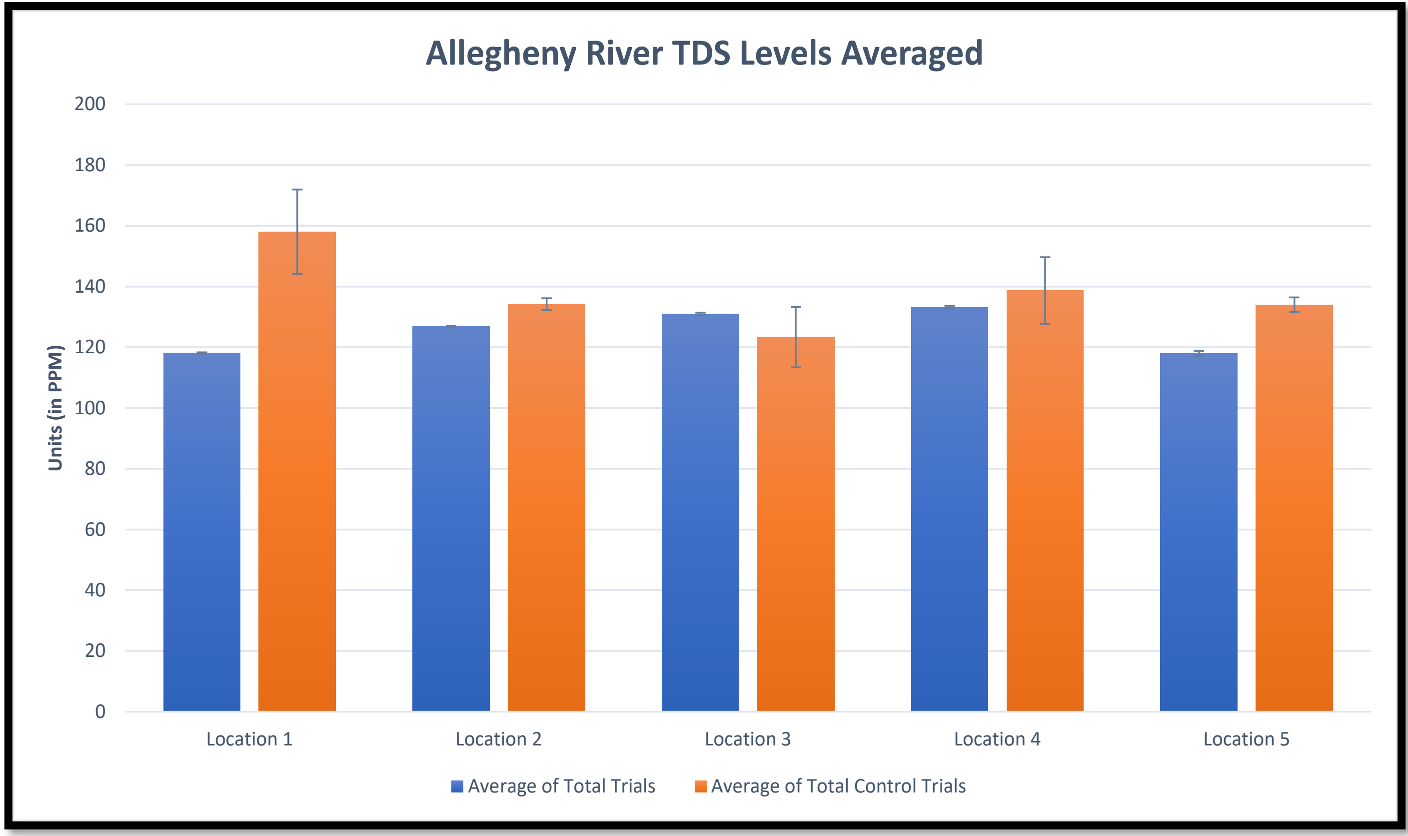
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	35.11	35.22	35.22	35.37	35.46	176.38
Average	7.022	7.044	7.044	7.074	7.092	7.0552
Variance	2E-05	8E-05	8E-05	0.00013	7E-05	0.000701
Treatment						
Count	5	5	5	5	5	25
Sum	35.15	35.16	35.24	35.42	35.6	176.57
Average	7.03	7.032	7.048	7.084	7.12	7.0628
Variance	0.0004	0.00022	7E-05	0.00043	0.00035	0.001488
Total						
Count	10	10	10	10	10	
Sum	70.26	70.38	70.46	70.79	71.06	
Average	7.026	7.038	7.046	7.079	7.106	
Variance	0.000204	0.000173	7.11E-05	0.000277	0.000404	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.000722	1	0.000722	3.902703	0.055136	4.084746
Columns	0.04308	4	0.01077	58.21622	3.79E-16	2.605975
Interaction	0.002048	4	0.000512	2.767568	0.040271	2.605975
Within	0.0074	40	0.000185			
Total	0.05325	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device’s and the industrial grade device’s data

Results Interpretation: Allegheny River TDS Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- The x-axis represents each location (there are two bars for each location because I tested my device and the industrial grade device) and the y-axis represents the units of measurement for each parameter
- Since most of the Standard Error bars are not overlapping, there **will** probably be significant variation between the two groups

Two-Factor ANOVA - Allegheny River TDS Levels

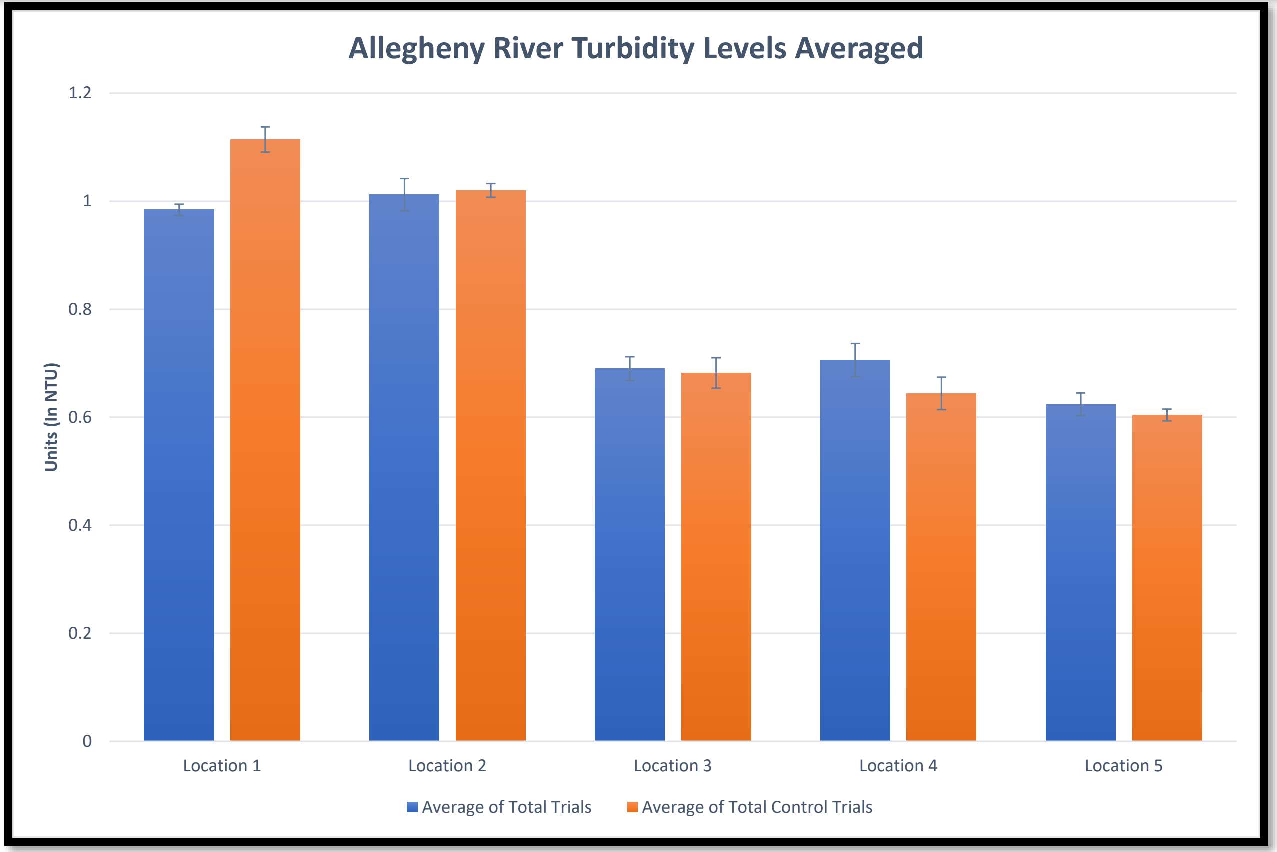
Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	790.4	670.8	616.8	693.6	670	3441.6
Average	158.08	134.16	123.36	138.72	134	137.664
Variance	965.072	19.328	492.848	599.952	29.2	486.1157
Treatment						
Count	5	5	5	5	5	25
Sum	590.1257	634.075	655.0135	665.2	589.7351	3134.149
Average	118.0251	126.815	131.0027	133.04	117.947	125.366
Variance	0.568632	0.367062	0.862477	1.55675	3.83599	43.2176
Total						
Count	10	10	10	10	10	
Sum	1380.526	1304.875	1271.814	1358.8	1259.735	
Average	138.0526	130.4875	127.1814	135.88	125.9735	
Variance	874.8381	23.7392	235.6521	276.299	86.26542	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	1890.518	1	1890.518	8.94458	0.004746	4.084746
Columns	1123.374	4	280.8434	1.32875	0.275969	2.605975
Interaction	3126.263	4	781.5657	3.69781	0.011833	2.605975
Within	8454.364	40	211.3591			
Total	14594.52	49				

- Since the p-value is less than 0.05 and the f-value is greater than the f-crit, there was variation between my device's and the industrial grade device's data

Results Interpretation: Allegheny River Turbidity Levels

Analytical Approach



BLUE bar – "Potamoi" Data (Experimental Group)
ORANGE bar – Industrial Grade Data (Control Group)

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device's and the industrial grade device's data

- Since most of the Standard Error bars are overlapping, there will probably be no significant variation between the two groups

Two-Factor ANOVA - Allegheny River Turbidity Levels

Analytical Approach

Anova: Two-Factor With Replication						
SUMMARY	Location 1	Location 2	Location 3	Location 4	Location 5	Total
Control						
Count	5	5	5	5	5	25
Sum	3.71	2.69	2.26	2.09	2.58	13.33
Average	0.742	0.538	0.452	0.418	0.516	0.5332
Variance	0.00227	0.00097	0.00077	0.00127	0.00673	0.015289
Treatment						
Count	5	5	5	5	5	25
Sum	3.67	2.73	2.06	2.16	2.67	13.29
Average	0.734	0.546	0.412	0.432	0.534	0.5316
Variance	0.00033	0.00138	0.00067	0.00257	0.00143	0.014689
Total						
Count	10	10	10	10	10	
Sum	7.38	5.42	4.32	4.25	5.25	
Average	0.738	0.542	0.432	0.425	0.525	
Variance	0.001173	0.001062	0.001084	0.001761	0.003717	
ANOVA						
rce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3.2E-05	1	3.2E-05	0.017401	0.895715	4.084746
Columns	0.640332	4	0.160083	87.04894	3.45E-19	2.605975
Interaction	0.005588	4	0.001397	0.759652	0.557724	2.605975
Within	0.07356	40	0.001839			
Total	0.719512	49				

- Since the p-value is greater than 0.05 and the f-crit is greater than the f-value, there was not significant variation between my device’s and the industrial grade device’s data

Acknowledgements

Thank You Judges!