FINAL CASE STUDY 2023

Project Title: All About Arsenic

School: Belfast Area High School

Grade Level: 10-12

Teacher: David Thomas

Project Partners: Jane Disney, Director, Research Training & Senior Staff Scientist at Mt. Desert Island Biological Laboratory (MDIBL), JuYoung Shim, Assistant **Professor** of Biology, UMA Augusta, Ramsey Steiner
Lab Manager, Dartmouth Trace Element Analysis Core

Teacher Profile: I have taught high school science in New York, Wisconsin, Virginia, and Maine for 23 years. I currently teach environmental science, physics, engineering, marine studies, and fish and wildlife management.
I studied limnology as an undergraduate at the University of Wisconsin at Madison. I later earned a Masters of Science degree in science education at Cornell University. I have worked in labs conducting aquatic research and have a keen interest in water quality research in both freshwater and marine systems.
I am interested in the All About Arsenic Project because of the project's relevance for students. I also am excited that the project engages students in areas of environmental health and water quality research, data literacy, and community outreach including civic action.

Summary:

In the Project Details section below, I have included some links and description regarding arsenic monitoring and data literacy.

Project Details:

- How many students were in the class that was involved in this project?

There were a total of about 75 students involved in at least some component of the All About Arsenic Project during the summer of 2022 and the 2022-2023 school year.

July 18 - Aug 11 Early College INT 188 course at UMaine Hutchinson Center
The main components of this course include data literacy, independent research, and career exploration. The course last summer took place shortly after the 2022 DataLit Institute, and so it was an opportune time to apply much of what I learned, including Drosophila and Planaria bioassays, as well as using TUVAlabs for many data literacy activities and analysis of research.

During the summer institute, we learned from Professor Doug Currie from the University of Southern Maine about using a climbing assay to measure the impact of toxicants such as arsenic on fruit flies. Two students in the INT 188 course tried this bioassay and collected some preliminary data. These students also experimented with planaria by exposing them to several toxicants and measuring both their regeneration and movement. The poster these students produced and presented is included here.

Students imported data from Drosophila and Planaria bioassays into TUVAlabs using this document.
Students also worked through several data literacy activities during the course, including the Remy Babich's Zebrafish toxicology dataset.

September 2022 - June 2023 Belfast Area High School AP Envtl Science and Advanced Physics

25 water samples from students in 2 classes were sent into the Dartmouth Trace Element Analysis Core Lab in February, 2023 for analysis of 14 elements including Be, Cr, Mn, Fe, Ni, Cu, As, Se, Cd, Sb, Ba, Th, Pb, and U. Once the sample results were received by students, we spent at least 2 class periods researching and exploring the toxicity of the various elements and using TUVA labs to explore previous student data. Once the 2023 student data was uploaded to TUVA, students were challenged to ask a scientific question that could be answered using the available datasets. This generated productive research and discussion. Students were especially interested to see how sample results compared between schools.
It is interesting to note that we had 2 student water samples that resulted in >100 ppb As concentration. In overhearing these students talk about their results, they seemed to feel no urgency to filter their water since they had been drinking the water all their life and they seem fine. After being motivated by one of our recent Office Hours Zoom meetings, I recently asked one of the students whose water was high in As if there were any health issues, he said that maybe stomach aches were very common in their household.

I am also the coach of the Science and Engineering Club at Belfast Area High School which consists of about 40 students. We have weekly lunch meetings. On many of these lunch meetings, we would explore datasets on TUVA labs and discuss these. We had discussions on several topics that were addressed in the 2022 Summer Datalit Institute including GIS mapping with ArcGIS online, public health and core data literacy ideas, data ethics, and social and environmental justice issues.

Students in the environmental science class created posters around some environmental issue in January, 2023.. These covered environmental pollution topics such as lead poisoning, arsenic in seaweed, and uranium in groundwater.

I used the information learned in the 2022 Datalit Institute and associated resources to work with students in the environmental science and fish and wildlife classes to conduct bioassays with Daphnia by loosely following the protocol from the Environmental Inquiry Program out of Cornell University. We conducted the Daphnia bioassay using arsenic solutions up to a concentration of 100 ppb. We measured mortality as well as changes in heart rate in the daphnia. We found that arsenic concentrations above 50 ppb had an effect on mortality but found no significant difference in heart rates with varying concentrations of arsenic. This was conducted in March 2023. During one of the Office Hours held in April, I was shown a TUVA graph on daphnia heart rates. This inspired me to try the experiment again. However, our data again showed high variability and no significant correlation between heart rate and As concentration after a 1, 2, and 5 minute exposure to arsenic solutions.

The students in my AP Environmental Science class are working on independent projects as part of their final assessment. One student designed a lettuce-seed bioassay using arsenic solutions modified from the Cornell's Environmental Inquiry Website. She will be writing a lab report and importing the data into TUVA labs for graphical representation and analysis, but her initial data in Google Sheets can found here.
Three class periods in the environmental science class were used to explore and discuss the importance and methodology behind Citizen Science Projects, such as is described by the California Academy of Sciences Citizen Science Toolkit. Students were led through exploration of various links found on the Data to Action Toolkit webpage on the All About Arsenic website. We had a guest speaker from the Waldo County Soil and Water Conservation District work with students to explore various citizen science projects on Anecdata for which they can contribute data (e.g., tree growth, tree disease reporting, water quality, etc.).
Students were given time in class to do some research and report out on each of the sections on the Data to Action Toolkit webpage. Their homework was to write a draft of a letter to the editor or a letter to one of their legislators. The students were somewhat reluctant to do this as they felt they didn't want their writing to be seen by others in the community. Several did write draft letters, and one student in particular wrote a strong letter that included data and evidence to help persuade homeowners to have their water supply tested. His letter to the editor is included here.

I am part of the Belfast Marine Institute at Belfast Area High School along with several other teachers and we started a kelp farm this year. We recently sent in a sample of our kelp to get tested for heavy metals and bacteria. Results from UMaine's Analytical Soil Testing Lab are included beow:

Sample type: Dried Kelp

Sample ID	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
1	44.0	1.03	< 1.0	2.50	1.07	< 1.0	36.8

	Hg mg/kg
2	< 0.01

Sample were ground to < 2mm prior to analysis.
Sample were digested by EPA Method 3050b and analyzed by ICP-OES.

The As concentration in the kelp seemed quite high, so I reached out to Ramsey Steiner from the Dartmouth Lab and asked her what she thought. She agreed that the 44000 ppb concentration (44 mg/kg) was high but in the normal range for kelp, which is a bioaccumulator. She shared a research paper about arsenic in seaweed species written by one of her colleagues, shared here.
Students in the marine studies class agreed this would be an interesting area to research further, so this will be a focus of next year's class.

- **Did you:**

Collaborate with any other teachers in your school?

I collaborated with the chemistry teacher to discuss results and the chemistry of arsenic and its cycling in living systems.

Go on any related field trips? Why and where?

We attended a virtual field trip to the Belfast wastewater treatment plant. Students in the environmental science class asked questions and learned about methods of water treatment. This water quality unit was motivated by our curriculum of testing student's well water samples and the Datalit Institute workshop.

Conduct any experiments? What kinds of questions did students ask?

We conducted bioassay experiments with Drosophila, planaria, Daphnia, and lettuce seeds. We worked to develop reliable methods and so our data was quite variable, but students were exposed to multiple lab skills and experimental methods.

Use your stipend to purchase anything for your classroom? If so, what, and how did you use it?

I used the stipend money to buy lab organisms and some lab equipment for both conducting bioassays (pipettors, petri dishes, lab vials, glassware) and sending water samples to the Dartmouth lab (parafilm, envelopes, plastic bin). I also purchased one teacher subscription for TUVA labs.

Invite any guests to visit your classroom?

As stated earlier, we invited the education director from the Waldo County Soil and Conservation District to show students various citizen science projects.

How did you use Tuva, both for the arsenic data and for other datasets?

During the summer of 2022 when I was teaching a UMaine Early College course on research, data literacy, and career exploration, we used TUVA as our main graphing program. We would analyze datasets and practice using the graph choice chart. Students also used TUVA to import their own research data for analysis and presentations on posters.

During the 2022-2023 school year at Belfast Area High School, I also used TUVA with students by going through a series of datasets and activities in the advanced physics and environmental science classes. I shared the graph choice chart with students. We explored the arsenic data portal website. Students worked in small groups to ask questions based on the datasets as well as make graphs to provide evidence for their reasoning.

How did you plan your community meeting or other outreach efforts:

We made posters of various environmental issues including effects of arsenic and posted them outside the classroom in the hallway.

We also discussed ways to make changes in the world and after we had a guest speaker from the Citizens Climate Lobby, we realized that changing policy was potentially the most impactful. I attended most of the All About Arsenic Office Hours via Zoom this school year. One of the office hours motivated me to plan a lesson around writing letters to politicians or the newspaper. So we tried that by writing draft letters, but that is as far as we went thus far with students.

In the future, I would like to engage in more community outreach around water testing, human health, and solutions. We could present to other schools in the district as well as present in front of the school board or Belfast City Council.

Data analyses examples

Posters with examples of TUVA graphs:

Clam predation poster

Planaria poster

Effect of Detergents on Zebrafish Embryos

Arsenic Bioassay with Lettuce Seeds

Discussion:

Students learned the importance of having their well water tested, and hopefully this instills in them a lifelong awareness of environmental and health impacts of contaminants such as heavy metals. When students were first told about the opportunity to get their water tested, they didn't know what to expect. But upon receiving results, they wanted to know the meaning of their results. They learned about MCLs, and strategies

for how to remediate water that contained high levels of contaminants. They also learned the proper method for collecting and shipping water samples.

By conducting trials with various organisms to assess the toxicity of various pollutants, students learned how to culture organisms in the lab as well as design controlled scientific experiments that can be replicated. I spoke with at least 3 parents about the water testing and they were grateful to have this service as part of the curriculum. One parent even commented that this helped teach their child about home ownership and the routine maintenance and monitoring that is required.

I learned so much from this project in terms of water chemistry, toxicology, bioassays, citizen science, and especially resources to help students become public advocates and carry out civic and community action around environmental issues.

I would like to have had more water samples tested, spend more time in class using TUVA, including importing data into TUVA. Students need more practice with data analysis and graphing. I also would like to invite more guest speakers to focus on community action. I also would like to work with one or more scientists partners throughout the school year, to include interaction between students and scientists partners.

Conclusion:

The All About Arsenic Project has been a great addition to my curriculum and provides a meaningful and important activity for students and their families. I hope the project continues and expands in future years, and that I can be part of the project and continue to collaborate with teachers and scientist partners.

References:

Babich, Remy, et al. "Defining Drinking Water Metal Contaminant Mixture Risk by Coupling Zebrafish Behavioral Analysis with Citizen Science." *Scientific Reports*, vol. 11, no. 1, 2021, https://doi.org/10.1038/s41598-021-96244-4.

Taylor, V. F., & Jackson, B. P. (2016). Concentrations and speciation of arsenic in New England seaweed species harvested for food and Agriculture. *Chemosphere*, *163*, 6–13. https://doi.org/10.1016/j.chemosphere.2016.08.004

Acknowledgement: The work reported in this publication was supported by the National Institute of General Medical Sciences of the National Institutes of Health under Award Number R25GM129796. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.