The Great Water Design Challenge: A NOAA Planet Stewards and Illinois Mathematics and Science Academy (IMSA) Collaboration

Liz Martinez

Abstract

Through generous NOAA Planet Stewards funding, schools in the Northern Illinois area had the unique opportunity to participate in a one-day design challenge that focused on local and state environmental issues. Student teams, which ranged from fifth grade through high school, engaged in research and design thinking to create innovative responses and solutions to address their selected water challenge. Subject matter experts were available, both virtually and in person, for questions, conversations, and insights as teams worked. Simultaneously team sponsors engaged in their own professional development related to the NOAA Planet Stewards Program. Students showcased their work at the end of the day to experts and educator mentors.

The Illinois Mathematics and Science Academy (IMSA, imsa.edu) is located roughly 40 miles west of Lake Michigan. When NOAA Planet Stewards contacted IMSA regarding developing and hosting a Planet Stewards workshop, we immediately thought of the Lake and named the event after Michigan, which means large or great lake, thus the name, The Great Water Challenge.

Planning the event was a team effort between NOAA Planet Stewards and IMSA's Statewide Educator Initiative Team (SEI). SEI's mission is to impact mathematics and science education by supporting educators with relevant professional development in areas such as technology, problem-based learning, the Next Generation Science Standards (NGSS, 2013), and a micro-credentialing program. SEI and NOAA Planet Stewards engage with formal and informal educators as well as students to increase scientific literacy. NOAA's focus on climate literacy (NOAA, 2006) and water-related issues closely aligns with IMSA's focus on the United Nations Sustainable Development Goals (UN, 2015), particularly goals 13-15. Earth and human activity, as well as engineering and design performance expectations from the Next Generation Science Standards, of which Illinois has adopted, are also interrelated.

Table 1. Event Goals

Source	Goal
United Nations Sustainable Development Goals https://sdgs.un.org/goals	Goal 13: Climate Action Goal 14: Life Below Water Goal 15: Life on Land
Essential Principles of Climate Literacy https://www.climate.gov/teaching/essential-principles-climate-literacy/essential-principles-climate-literacy	Essential Principle 6: Human activities are impacting the climate system. Essential Principle 7: Climate change will have consequences for the Earth system and human lives.
Next Generation Science Standards https://www.nextgenscience.org/	**Middle School** Earth and Human Activity: MS-ESS3-2, MS-ESS3-3, MS-ESS3-5 Engineering and Design: MS-ETS1-1, MS-ETS1-1, MS-ETS1-4 **High School** Earth and Human Activity: HS-ESS3-1, HS-ESS3-4 Engineering and Design: HS-ETS1-1, HS-ETS1-2, HS-ETS1-3

Allowing student choice, using local issues, and connecting learners with experts in the field were the best pedagogical practices used as criteria for the project development. These led us to employ a modified design sprint. The function of a design sprint is to identify a problem and solve it within a short amount of time, usually five days, through research, discussion, ideation, and prototyping. As this was a one-day event, teams were not expected to complete a significant portion of the design sprint process. Teams would identify a local environmental problem they wanted to mitigate, research the issue, and develop a plan of action or solution. In order to narrow the field of issues for the students and the teachers, a focused list of locally relevant topics was developed. Categories were selected based on local environmental issues, recent events, appropriate resources, and availability of subject matter experts. Research questions were then developed for each of the categories. Below is the list of topics and questions.

Algal Blooms, Pet Illnesses

- How does the Midwest contribute to harmful algal blooms in the Gulf of Mexico and how can we lessen the impact?
- How do harmful algal blooms affect plants, animals (including pets), and humans?
- What are potential solutions to reducing harmful algal bloom events?

Algae

- Why are algae necessary for the biosphere?
- How can uses of algae positively impact climate change or sustainability?

Biodiversity/Invasive Animal Species

- How is climate change affecting the spread of invasive species (such as zebra mussels)?
- What are the impacts of invasive species (such as zebra mussels)?
- What actions can be taken to control invasive species (such as zebra mussels)?

Biodiversity/Invasive Plant Species

- How is climate change affecting the spread of invasive plant species (such as purple loosestrife)?
- What are the impacts of invasive species (such as purple loosestrife)?
- What actions can be taken to control invasive species (such as purple loosestrife)?

Marine Debris, Microplastics, Plastics

- What are the trends in the use of microplastics and what actions can be taken to reduce what ends up in the ocean?
- Document the presence of marine debris in the Great Lakes and what communities can do to reduce the input.

Human Health Issues, Vector-borne Disease

- How is climate change affecting the incidence of vector-borne diseases?
- What actions can be taken to reduce the incidences of vector-borne diseases?

Nuisance Flooding, Weather Incidents, Shoreline Changes

- What are the impacts of flooding events in Illinois and what strategies are communities using to protect citizens and property?
- Document how climate change may affect the incidences of severe weather. What actions should citizens take to prepare for the new climate future?

During registration for the project, student teams selected the question they wanted to investigate, subject matter experts they wished to hear, and submitted questions they wanted to ask each of the subject matter experts at the event.

Teams were provided with resources to use for preliminary research prior to the event. Many student teams came prepared with extensive background knowledge about their chosen issue. This allowed them to focus on having final questions answered from the experts and to develop solutions and evidence to support their choice.

Planning for a one-day event that provides an immersive experience for students requires an attention to detail. Scheduling for the day included general sessions and customized sessions for each school to meet with their subject matter experts of choice. Identification of and communication with subject matter experts was critical. Presentation materials, topics and questions from teams, schedules, and technical platforms needed to be developed and shared. School and student permissions, schedules, and other logistics for the day also needed to be sent in advance. Some of the responsibilities for the hosting SEI team included facility reservations for large and small group work, food, check in, moderating sessions, obtaining and providing materials for teams, and supervising students. We also wanted to provide the sponsoring teachers with their own professional development. NOAA Planet Stewards Program, NOAA resources, implementation ideas, and other related topics were presented at an educator-only session during the event while the students worked with the subject matter experts.

The day of the Great Water Challenge began with all participants gathered in the auditorium. Subject matter experts introduced themselves, briefly spoke about their jobs, and shared their areas of expertise. From there teams moved following their individual schedules as they met with the subject matter experts either in-person or virtually, who presented additional background information regarding their topics and answered student questions.

Each team then began developing ideas to mitigate their selected issue, as well as a presentation and materials for the poster session in the afternoon. For the final session, student teams were divided into groups A and B. This allowed group A teams to present and group B teams to move about and listen to group A team presentations. Roles were reversed so group B teams presented for group A teams. The day wrapped up with awards that recognized creative efforts, scientific accuracy, and clarity of solutions. Teams were also presented with *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming* by Paul Hawken, water bottles, and metal straws.

Table 2. Sample of Student Developed Questions

- How do you think AI can help solve the issue of invasive species?
- Do invasive species cause long term human health issues? If so, what kind and what have we done in the past to prevent / stop them?

- What does marine debris encompass? Please provide categories or examples.
- Is it possible to introduce catalysts that will re-polymerize microplastics so they can be combined into larger molecules that are easier to extract?
- Are there any projects where algae or bacteria are being used to breakdown plastics or marine debris?

- In what ways do algae benefit the ecosystem compared to what they take away?
- How do algae compare to other marine/aquatic plant life?
- Could there be blooms of any other plant species that cause as much harm as algal blooms?
- What is the main cause of algal blooms? Where is it most prevalent?
- If algae is helpful to ecosystems, how does it also cause harm?
- Could the impact of algae blooms extend as far as the Midwest and affect our drinking water supply?

- Once an aquatic system is thrown off-balance, can it fully recover, and how?
- What types of laws or regulations have been put in place to regulate the use of fertilizers?

Figure 1. Dennis Liu talks with a student about biodiversity and invasive species.

Photo credit: Angela Rowley

Figure 2. Students engage with a virtual expert to learn more about their chosen topic.

Photo credit: Angela Rowley

Impact

The impact of the Great Water Challenge is largely anecdotal in nature. Participant numbers included 25 educators, 87 students, 6 subject matter experts, and 10 IMSA SEI Team members. Comments during the day were very positive from the students, the participating educators, and the subject matter experts.

Participant comments included

- "Our students thoroughly enjoyed the day. They have been talking about their idea to all of their teachers." – *Educator*
- "I didn't know that what we do here bothers the ocean." – *Student*
- "Why aren't there laws to stop that? " – *Student*
- "This is the best day of my life!" – *Student*
- "I met real scientists." – *Student*
- "Students were well prepared. They asked really good questions and had great ideas." – *Subject Matter Expert*
- "They are persistent." – *Subject Matter Expert*
- "It was refreshing – their perspective." – *Subject Matter Expert*

As a pilot project, the design challenge may provide a spring board for more opportunities so that students may interact with subject matter experts regarding a wide range of environmental issues.

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About the Author

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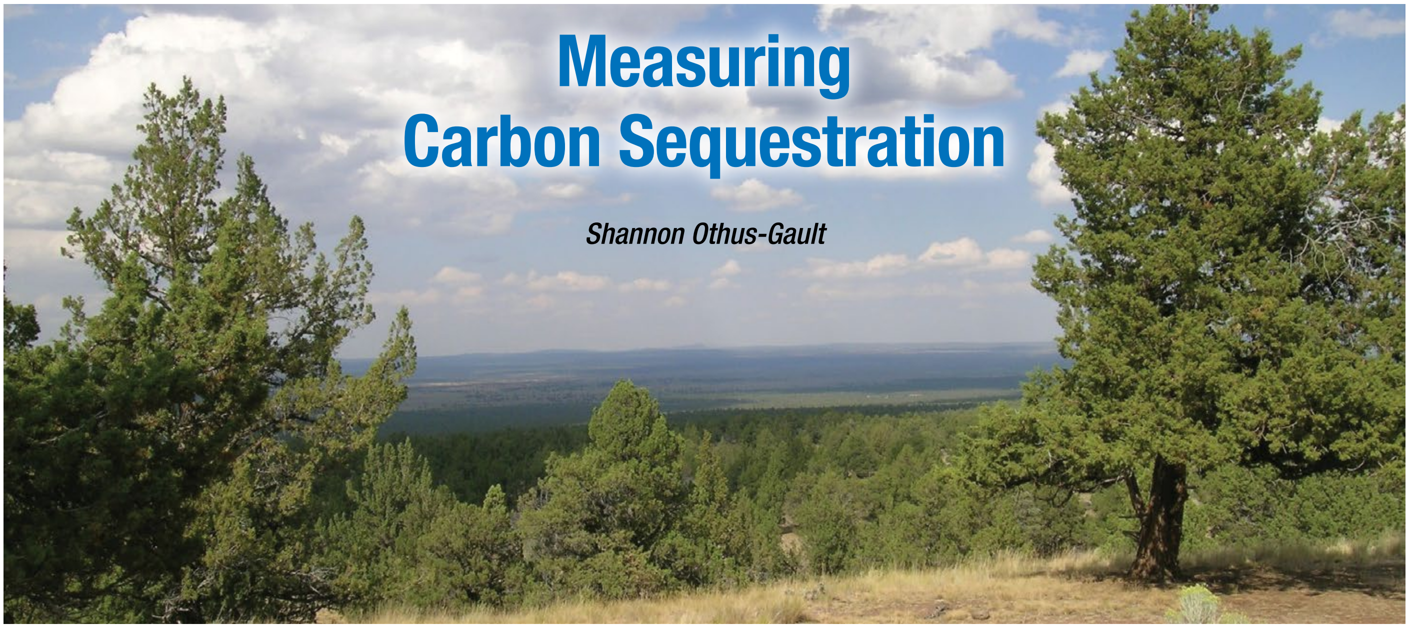
Measuring Carbon Sequestration

Shannon Othus-Gault



Abstract

Carbon sequestration by plants is one of the most important short-term processes that removes the greenhouse gas carbon dioxide from the atmosphere. As humans continue to release carbon from long term geologic sinks, through the burning of fossil fuels for example, understanding how carbon can be removed from the atmosphere by plants through photosynthesis is an important concept for students to understand. One way to attempt to measure this process is by measuring dry and ash weights of a plant to estimate the amount of carbon sequestered by the plant during its lifetime. This laboratory activity can be paired with the creation of a community garden that allows students to measure how much carbon can be sequestered through the creation of an individual green space and can connect to individual action on climate change. The green space used during the creation of this laboratory activity was funded by the National Oceanic and Atmospheric Administration (NOAA) Planet Stewards Program in 2018 (https://oceanservice.noaa.gov/education/planet-stewards/).

Introduction

The atmosphere is made out of many gases and some of those trace gases are referred to as greenhouse gases. These gases are important for the atmosphere because they absorb infrared and emit their own infrared, heating the lower atmosphere. The heat given off by greenhouse gases creates a livable climate on Earth, a whole 33^{0}C warmer than it would be without the presence of greenhouse gases (ESRL, 2005). One of the most important greenhouse gases is carbon dioxide. Carbon dioxide is also an important gas in terms of plant growth. Plants use carbon dioxide from the atmosphere during the process of photosynthesis to create biomass (NOAA, 2019). This process of obtaining carbon from the atmosphere and holding it in solid form is referred to as carbon sequestration. Carbon sequestration has become more important in recent years with the increase of carbon dioxide in the atmosphere creating an enhanced greenhouse effect and contributing to the warming of our atmosphere. In fact, historical levels of carbon dioxide remained below 300 ppm (parts per million) over the past 400,000 years; yet, since the 1950's, carbon dioxide has increased to over 400 ppm (NASA, 2016).

All humans can help to sequester carbon from the atmosphere by creating their own gardens and increasing biomass on Earth's surface. This goal of this laboratory activity was to teach students about important atmospheric processes, including the greenhouse effect and how atmospheric carbon can be sequestered by plants. Another goal of this activity was to measure the amount of carbon that can effectively be sequestered in a small green space as an example of what they can do in their own home and/or yard.

Methods

Prior to performing this lab activity, my students were provided information on the greenhouse effect and the carbon cycle and also participated in class activities related to biogeochemical cycles and greenhouse gases, such as those provided by the Science Education Resource Center (SERC) through the EarthLabs project (SERC, 2016). This base knowledge was provided to allow students to connect the related lab activity to much larger Earth systems and processes. After finishing pre-lab work, students began to measure carbon sequestration by obtaining a whole-plant sample, including the root system. A sample can be collected from a school garden (as was done for this project) or can be collected from any appropriate place noted by an instructor or even parent. Once the sample was obtained, the whole plant was cleaned to remove as much excess soil as possible so that the most accurate dry weight of the plant sample could be measured. Once cleaned, the plant was dried. I allowed samples to air dry over several weeks; however, you could attempt to dry the plants more quickly in a low temperature, drying oven. Once these samples were dried, they were used by students to measure the carbon sequestered by the plant. To do this, the dried plant was weighed and that weight recorded. Next, the dried plant matter was burned in a controlled manner so that ash can be collected and weighed.

Figure 1: Picture shows the author demonstrating to students how to combust plant samples.

Photo Credit: Shannon Othus

By subtracting the weight of the ash from the weight of the dry sample, students were able to roughly estimate the amount of carbon that was sequestered by that plant. This activity works by essentially combusting the carbon matter in the plant and creating carbon dioxide, which is transferred to the atmosphere, and leaving behind the rest of the noncombustible matter of the plant. By comparing the dry weight with the ash weight, we can make a rough estimation of the carbon that had been contained in the plant sample.

Although measuring the carbon sequestered by a single plant can be useful, students can use plant counts within a garden to calculate how much carbon a larger green space or garden can sequester. During this activity with my own class, we obtained the amount of carbon sequestered by our garden by creating a garden map and counting the number of the different plants present in the garden.

Figure 2: Picture showing the community garden and the distribution of plants used to measure carbon sequestration.

Photo Credit: Shannon Othus

Once students created their map and finished their plant counts, they multiplied the number of each example plant counted by the measurement of the carbon that type of plant sequestered. These final carbon calculations were added together to create a rough estimate of how much carbon was sequestered by our garden during that year's sampling. These easy measurements can potentially allow students to plan for future growing seasons to maximize carbon sequestration with evidence-based observations from past growing seasons.

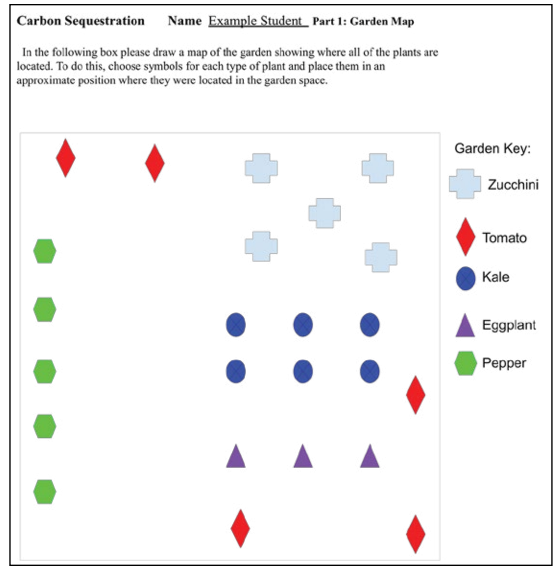


Figure 3: Map shows the placement and number of plants found in the Yamhill Valley Campus Community Garden. The plant counts found on the map were used by students when calculating the total carbon sequestered in the garden through multiplying the number of plants present with the carbon measured by students.

Materials and Suggestions

This is clearly a lab activity that needs to be well supervised by an instructor due to the fact that fire is involved. Also, after students performed this lab activity for the first time in my classroom, I learned several tricks and tips for what materials are more successful for this activity and how to use those materials to fully incinerate the dry plant material. One of the most important materials you will need is a receptacle to burn your dry plant material. I obtained large food cans from the kitchen on our campus and they were big enough to allow for full combustion. You will also want to make sure that there are ventilation holes in these receptacles so that air can mix with the plant material during combustion. Also, make sure that the holes aren't big enough to lose ash material. Another possible tip to allow for combustion to occur more rapidly would be breaking the plant into smaller pieces prior to incineration so the volume of the plant is more compact. I have also found that stem lighters are best for keeping appendages away from the flames but are also useful in continuing the combustion of materials if they need to be set alight more than once. Lastly, I would suggest heat resistant gloves to protect student hands.

Student Assessment

Due to the current pandemic, I have only been able to run this lab activity with two classes using mature plants from my campus's community garden. However, students were able to work together to calculate some estimates of carbon sequestered by the plants in our garden. Some of the dried plants were not able to be fully burned leading to a low overall calculation for the carbon sequestered by plants in the garden, kale plants in particular. Results based on student calculations from the Spring of 2019 can be found in Table 1.

Table 1: Data collected and calculated by students to calculate carbon sequestered within the Yamhill Valley Campus community garden from the 2019 General Science Earth System Science class

Year and Season	Age of Plant	Plant Type	Dry Weight (g)	Ash Weight (g)	Carbon Weight (g)	Number of Plants	Total Carbon Sequestered (g)
Spring 2019	Adult	*Kale	23.6	22.3	1.3	6	7.8
Spring 2019	Adult	Peppers	80.6	11.9	68.7	5	343.5
Spring 2019	Adult	Zucchini	310.0	128.0	182.0	5	910.0
Spring 2019	Adult	Tomatoes	271.1	39.0	232.1	5	1160.5
Spring 2019	Adult	Eggplant	97.6	17.3	80.3	3	240.9
						Total carbon sequestered by adult garden:	**2662.7**

* Incomplete burn of specimen

Once students had finished calculating their measurements, they were then asked to answer several questions to put their carbon measurements into greater context of the greenhouse effect and climate processes, i.e., how does growing plants change the atmospheric concentration of carbon dioxide and, therefore, affect the greenhouse effect? The questions that I posed are as follows:

- How does carbon dioxide behave in the atmosphere (hint: what type of gas is carbon dioxide)? How can an abundance of carbon dioxide in the atmosphere become a problem for Earth's biosphere?
- Vegetation is considered a carbon sink. Based on the word "sink", what do you think that suggests in terms of the carbon that was sequestered by the plants you measured? In other

words, how is the carbon sequestered by plants related to the carbon dioxide found in the atmosphere?

- How can sequestered carbon change the composition of the atmosphere? How could this sequestration affect the greenhouse effect?
- Knowing that this garden was used for food production, how can the harvesting of food from the garden affect the carbon weight measured? How does harvesting food from the garden affect the number that you calculated for the total carbon sequestered by the garden?
- Can you think of any other sources of error that could have affected the calculations you made for carbon weights and the amount of carbon sequestered by the plants in the garden?

These questions allowed students to think deeply about how plants and atmospheric composition are directly linked and how the greenhouse effect can be affected by plant growth. It also asks students to think about errors in their calculations since this activity is truly, a very rough estimation of carbon sequestration.

Conclusion

Allowing students to connect their own personal activity to atmospheric composition and the greenhouse effect is an important lesson to learn as we begin to tackle the effects of anthropogenic climate change. This is a lab activity that is hands-on and allows for teachers and students to use green spaces, whether at school or at home, and for scientific exploration and data collection, which are important aspects of inquiry-based science learning.

A list of materials, methods and lab questions, can be found at:
https://docs.google.com/document/d/1eXa3vbX7uncsJr0hh37Kxz4MOQHbFwPrB1IOLAVqK0A/edit?usp=sharing

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About the Author

Shannon Othus-Gault began teaching as an outdoor school and science camp instructor at the age of 16 and has worked in the states of Oregon, Washington, California, New York and Wisconsin. Shannon has been teaching geology and Earth sciences for ten years at several Community Colleges but has committed to a single location, Chemeketa Community College at the Yamhill Valley Campus in McMinnville, Oregon. Prior to teaching, Shannon worked as a natural resource scientist for the Washington Department of Natural Resources in the Forestry department mapping landslides and making landslide hazard maps. She can be reached at othussm@gmail.com