LEXUS ECO CHALLENGE 2019-2020

Where can you see the CO_2?

Follow the Carbon!

Air and Climate Challenge

- **Teacher Advisor:** Janet Ort
- **Team Name:** BioBucs
- **Team Members:** Reid Markland, Abhinav Gullapalli, Carson Perry, Noel Ponder, Abi Collins
- **School:** Hoover High School
- **School city and State:** Hoover, Alabama
- **Principal name:** John Montgomery

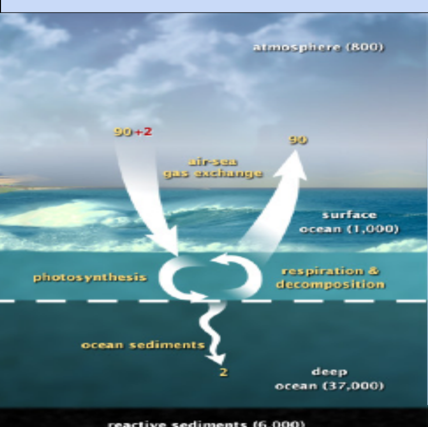
PART 1—Issue: What's the Environmental Issue?

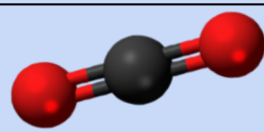
One of the most pressing issues of today's world is climate change. Global warming is caused by increasing Greenhouse Gases in our atmosphere thickening the atmospheric blanket & retaining more heat below the Greenhouse Gas layer. Carbon compounds are some of the most influential heat retaining gases.

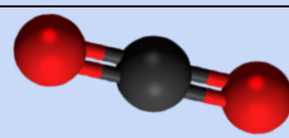
Nearly all of the carbon that cycles through the atmosphere is in CO or CO_2 form with the amount of CO_2 being around 2000 times larger. The C molecules represent boh current cycling C and ancient C that was fixed during ancient photosynthesis. The ancient Carbon has been stored in fossil fuels. Since the Industrial Revolution, the concentration ratio of ancient C has drastically increased due to their combustion & extraction.

One impact of increased atmospheric C is increased C movement into water through diffusion.This alters the water chemistry, especially of the ocean., When C concentration is altered, it has significant adverse effects on both the ecosystems within the ocean and the organisms that live there, for example pH. A lower pH can change C absorption and dissolve C based shells. Having an accurate way to track the passage of carbon in and out of our bodies of water will allow us to better understand the movements of carbon throughout the all ecosystems.

Translating the complexities of the carbon cycle is vital to conveying the magnitude of our current climate change crisis to up and coming environmental researchers. This is something which is hard to accomplish as the complexities of the carbon cycle are often lost on students taking environmental science classes. This applies especially to the diffusion of carbon into water. Ms. Ort's experience teaching in an environmental science classroom confirms this. Part of the problem, we decided, lies in the lack of access to a more simple visualization of carbon diffusing into and out of water than the full scale model the textbooks provide. In addition, connecting the increase of tree mass with C is difficult. Understanding the pieces of the cycle individually can help to complete the full puzzle of the carbon cycle in the minds of students.







Cycle of Carbon Through our Oceans

(numbers are gigatons of carbon per year, red is human contributions, white is stored carbon, yellow is carbon movements)

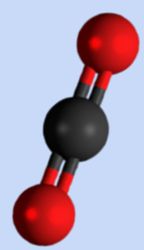


Image from NASA Earth Observatory

PART 1—Issue: What Inspired Us to Take Action

“Racing Extinction” is a documentary about people creating art to visualize human impacts on biodiversity. Both images of endangered animals and enhanced images about CO_2 & CH_4 emission were projected in massive formats. In each example, the film documented people’s reactions to the images and how their behavior changed afterwards.

The film also emphasized the importance of starting with ONE thing. This idea is so important and powerful in a region where we have so many climate change deniers. By building consensus around smaller, more measurable portions of the climate systems, you can build understanding that breaks through climate denier indoctrination.

CO2 visualization from “Racing Extinction”

Start with One Thing inspiration from “Racing Extinction”

According to the GLOBE program “Tree height is not just a measurement - it is a gateway to understanding many things about the environment. The structure of tree canopies, the 3D arrangement of individual trees, has a huge effect on how ecosystems function and cycle through carbon, water, and nutrients” Ms. Ort is increasing the use of GLOBE Protocols with her environmental science classes. We think these well established procedures will be important to develop long term studies. as the students become more proficient, they will be able to compare their data to world wide data. That may lead to GLOBE Research too.

Industry Standard under water Equipment required for labs measuring CO_2 Respiration Rates range in the $2,000-$3,000 range, according to various instrument supply companies. This price makes the lab inaccessible to most schools. Vernier is well accepted in many schools. Because of the inaccessibility to necessary equipment for studying the Carbon Cycle, we want to developed a cost-effective 3D printable device to store the Vernier sensor during labs in water ecosystems.

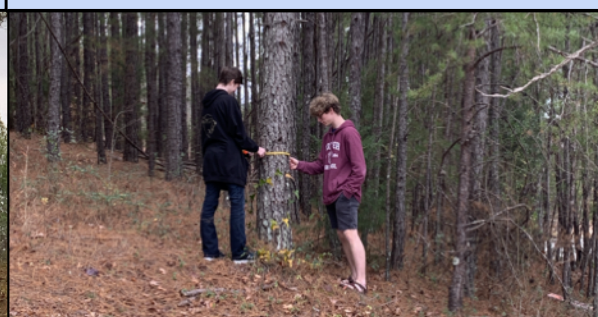
PART 2—Plan: What's your Action Plan?

Team responsibilities:

- Reid - Engineer, Design, Programming, Field Research
- Carson - Engineer, Design, Technician, Tree Mapping, OCD Fanatic
- Noel - Communications Leader, Game Developer, Field Research, Construction
- Abhinav - Field Research, Web Development, Tree Map Developer
- Abi - Field Research, Tree Mapping

Abhinav and Abi, Measuring Trees

Noel and Reid, measuring tree circumference.



Carson, working on Solidworks

BIOBUCS
HHS ENVIRONMENT

Because of the success of our Lexus Project last year and successes in other STEM competitions, Ms. Ort was designated the STEM Team Coach. She was given a class period that meets every day for BioBucs and STEM Team. We also met after school 3 days, and over a holiday 1 day during the Climate Challenge time period.

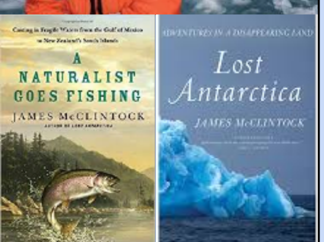
Instagram: @hooverstem
Website: bit.ly/BioBucs

PART 2—Plan: What's your Action Plan? (continued)

GOALS:

We want to start a domino effect of schools talking about the increasing rate of climate change. Climate change is dangerous not just to our health now but to future generations of all species on Earth. Through reading papers and listening to talks by Dr. McClintock, we've learned that children are most sensitive to environmental changes, particularly degrading environmental conditions. Thus, children are more susceptible to respiratory diseases. By providing students with a way to easily study environmental changes, climate change in particular, we believe students will be well-equipped to take action and contribute to a more sustainable future. CO_2 is a primary contributor to the increasing rate at which climate change is occurring, so we can take the first step in empowering future generations by helping them study the Carbon Cycle.

We hope to have Dr. McClintock come and speak at our school, and we will measure success by the number of people who attend the event. Greata Thungerg is also someone who comes to mind when talking about involving young people in the climate change discussion because she was inspired to speak out at such a young age.



The ability to collect CO_2 data over a long period of time in different environments in a cheap and efficient manner is a primary goal of our project. This will allow us to reach other schools and local organizations (like Verner) by creating easily replicable vessels to be used in labs. In addition to downloadable 3D print models, we can publish instructions for a homemade chamber that would enable schools in less fortunate communities to replicate these labs just as easily. All Schools need is access to a Vernier GoDirect CO_2 Sensor. Data recording from the sensor can be uploaded to any smartphone or computer, making the lab extremely accessible. As students learn about the movement of CO_2 through cellular respiration, they will come to an enhanced understanding of diffusion in and out of the water with our hands-on lab.

We also want to map some trees in the area in order to aid us in tracking the elements of the carbon cycle. Since trees are C sinks, measuring the different types, hights, and circumferences of trees can help show students how C moves around them which will help lead to discussions how C moves. When burning fossil fuels C which was previously 'locked away' is released into the atmosphere. This C is purely additive to the net amount of C circulating. Some of this C is sequestered in trees. Tracking the growth of trees allows us to predict how much C is being removed from our atmosphere and better understand the carbon cycle.

In addition to the labs, we would like to work towards creating some kind of game which will cement the ideas expressed through our labs. Jenga would be a simple game to modify since the rules are commonly known and a teacher could purchase it little cost.

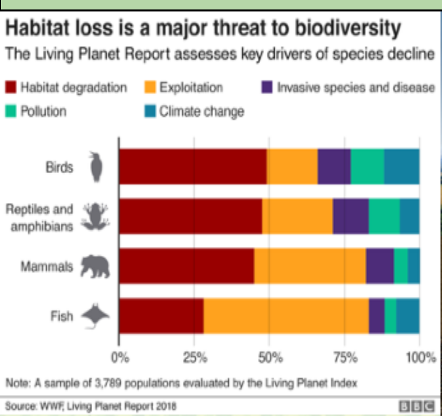
PART 2—Plan: What's your Action Plan? (continued)

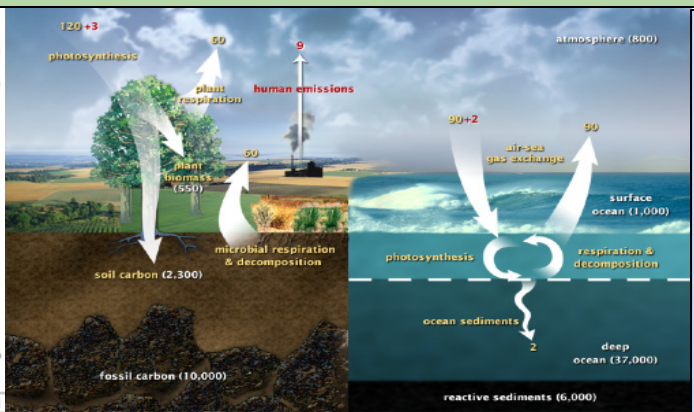
We want to develop a procedure to demonstrate the movement of CO_2 through water. We will design an easily replicable vessel that could carry a CO_2 sensor over a body of water during an extended period of time. This will allow the sensor to record CO_2 diffusion rates over any sitting body of water. The sensor can connect to the lab quest or to the Vernier GoWireless app on phones and computers. This would allow us to create a lab in which the teacher, or a student could blow into the bio chamber and then quickly place the vessel back in any body of water and students could see in real time the CO_2 diffusing out of the air in the chamber and into the water. A more extensive sample could collect cellular respiration and decay release CO_2 under water. Diffusion in and out of water is something that is particularly hard for students to conceptualize, and this lab would give teachers a way to show students carbon actually moving in or out of water.

We know our design has to fulfil a set of parameters. First, the CO_2 sensor will not be able to come into contact with water because it is not waterproof. Second, the vessel will have to be able to stay in place over an extended period of time so they will always be in range of our recording systems. Third, and most importantly, we need our vessel to be easily replicated. We want any science class to be able to produce the vessel that could hold the sensor so anyone could do this lab, or something similar in their classrooms. We plan to quantify success by making a working vessel that could measure carbon as it moves in real time was another way are going to measure success, so that we could have it reviewed and hopefully support our design. We also hope to be able to share our tree data with others.

Climate change often results in loss and degradation of habitats. These are the top reasons for loss of biodiversity. We want to have room in our project to expand towards addressing that link. We want to take the first step towards that link by also recording what types of trees are going to be mapped, and hopefully in the future we can look at the biodiversity of our local wildlife.

Vernier GoDirect CO_2 Sensor

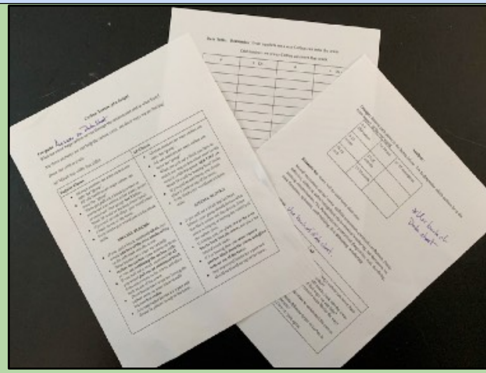


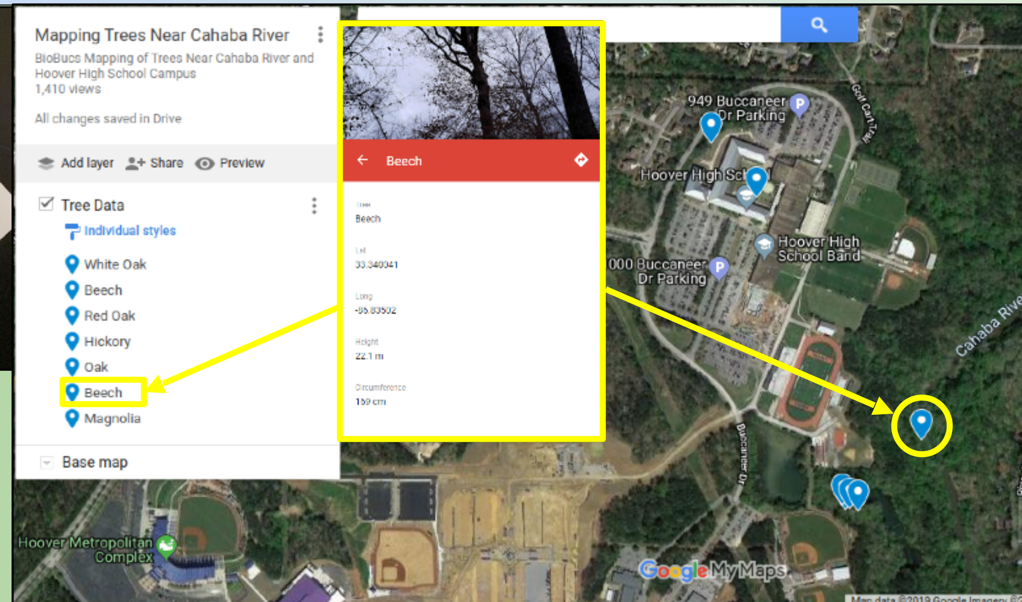


We Plan to…

- Plan an event to raise community awareness of Climate Issues
- Design a method/tool to measure movement of carbon through water.
- Create Student Activities that model movement of Carbon through the ecosystem
- Implement Longitudinal studies focused on monitoring local trees.
- Share all of our data and designs!

PART 3—Implementation: Carbon Towers & Tree Mapping





We wanted the game Carbon Towers to show the movement of carbon through different carbon sinks and help students learn how it got there. All of the blocks come numbered so we will assign groups of number to different places carbon can be found like the ocean, air, soil, etc. The even blocks would represent ways carbon can enter the assigned place and odd would be ways carbon can leave that place. The students are given pregame, analysis, and reflection questions to test how much they learned from the activity. In the analysis, they will tally the C in each grouping and compare that data to known C sinks. A teacher guide will help guide the discussion & analysis towards deeper understanding.**(See Documents above)**

Students building Carbon Towers

Using Google's MyMaps, we began mapping trees near the Cahaba River and the Hoover High School campus. We improved our map to make it more accessible and user-friendly. Using the GLOBE Observer TreeFinder app, we documented the name and a picture of each tree, the tree's longitude and latitude, and the height and circumference of the tree. As shown in the screenshot above, each plotted data point provides these details about each documented tree. The trees indicate a possible carbon sink in the carbon cycle, allowing us to study the different types of trees in the area and how much carbon each tree can annually sequester. All environmental science students will continue to document more trees as part of a nationwide longitudinal study to document the biodiversity of trees. This map will be used by all environmental science students to track tree growth and evolving biodiversity over time.

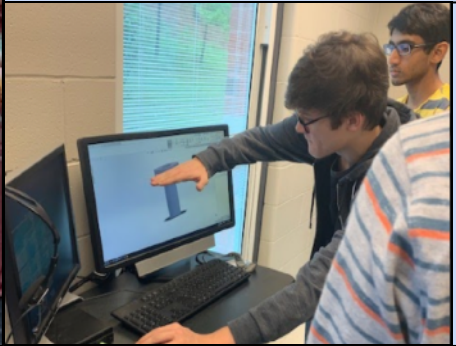
PART 3—Implementation: Design & Testing of Flotation Device

Noel using silicone caulking for our prototype

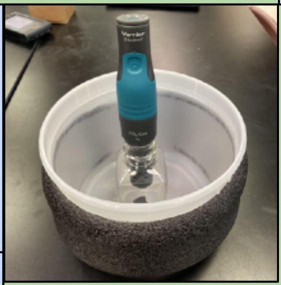
The first design for our vessel (Model 1) involved surrounding a CO_2 sensor with foam, which would make it buoyant enough to float. However, we found that simply surrounding the sensor did not give enough support and led to constant unbalance. We decided that the vessel would have to have more surface area in contact with the water in order to prevent it from tipping over. Our second design involved punching a hole through a plastic bucket and sealing a biochamber that the sensor could fit into in to above the hole.We needed to seal the chamber so that no atmospheric carbon could interfere with the data collection. We originally tried to use candle wax to seal the chamber, but it was too fragile and broke almost immediately, we tried to fix it with duct tape and that also did not work. after candle wax and duct tape we tried to use silicone to seal the chamber, and it worked great, it popped off once but was easily stuck back in place. After proving the viability of our second design, we decided to evolve our design by using solidworks, an industry-standard Computer Assisted Drawing (CAD) system used by engineers world-wide, to create 3D models of the designs.

Model 3 undergoing a stress test in a bucket of water.

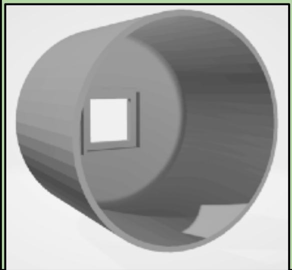
The sensor Model 2 was placed in the pond (**top left**) while Abhi, Reid, and Carson (**bottom left**) monitored and recorded the data. It was a very cold day for AL.



Carson, Abhi, and Reid using SolidWorks, a CAD system, to model the designs (**left**)



Physical Models of 2 and 3



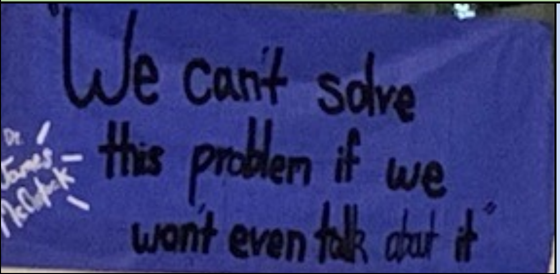
3D Models of 2 and 3

PART 3—Implementation: Community Outreach

“We can’t solve this problem if we won’t even talk about it.” -Dr. James McClintock

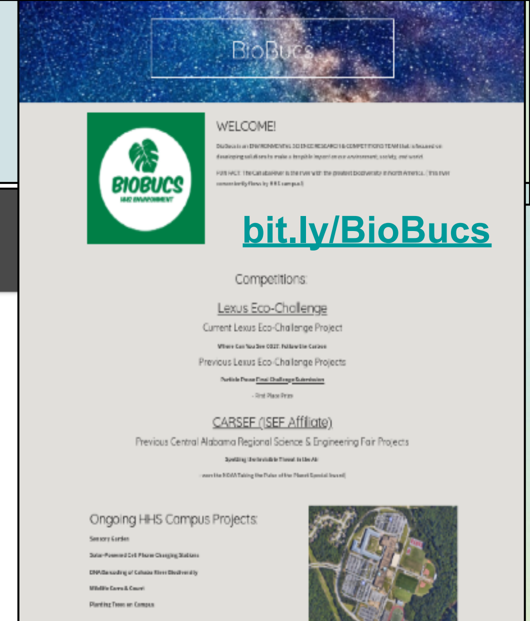
The complexities of climate change models and climate science are difficult to understand for some people. In addition, we live in an area of the country that often embraces climate change **denial**. Summer 2019 our sponsor, Ms Ort, went to an AP Env Sci (APES) training with 4 other local APES teachers. They agreed to co-sponsor events for the 4 hgh schools plus the community. We hoped to reach 175 students. Ms. Ort has attended workshops with Dr. James McClintock (Dr. M) over several years. She has used his scientific papers & book excerpts in her classes. She contacted him to speak at the opening event Penguins, Fish, Ice, and the Future. He agreed even though he later told her he expected about 20 people to show up. He also waved his substantial fee. He is a VERY important Antarctic specialist. He has ongoing research for 30+ years. He has authored MANY scientific papers & 2 popular books. He is a very effective, world renowned speaker & advocate. He also spoke of his career pathway that includes many aspects of STEAM skills. Our school SGA made welcome signs inside and on the outside marquee. Our Hoover Ambassadors helped direct visitors that just kept coming that night. Our choral dept & maintenance dept helped with set up and chairs. We sent emails to mailing lists for the Cahaba River Society, people that attended Dr. M’s workshops, and made daily announcements in all of our schools.

Dr. James McClintock is the Endowed University Professor of Polar and Marine Biology at University of Alabama at Birmingham, and is an award-winning climate communicator. He is a Trustee for The Nature Conservancy of Alabama, and also a spokesperson for The Nature Conservancy’s “Can We Talk Climate” . He is also a board member of the Cahaba River Society.

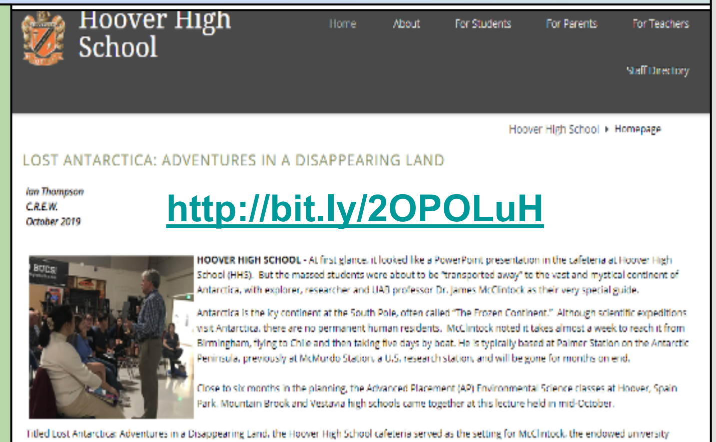


Panorama of our Audience

PART 4—Results: Outreach

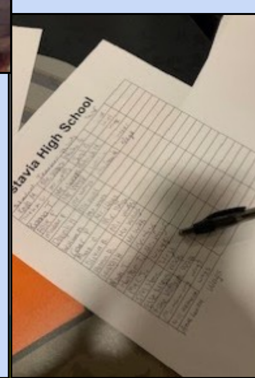


- Attendance: 240+ from 4 HS, Samford U, the community
- **Dr. McClintock was VERY Happy his average #s are 100**
- 10 Ambassadors helped direct people
- 10 SGA members made signs and posted them
- Post Event Article written for the HHS website which reaches 13,500 /month
- After the event teachers discussed how student attitudes were changed 179 potential students
- 125 flyers (8.5 in x 11 in) & 5 large posters (3 ft x 2 ft) around the school



What did we learn?
We learned from Dr. McClintock that we must be able to communicate science in a powerful manner to encourage collaboration for problem-solving Also, we should never be afraid to ask famous people to help. Our community is hungry to learn about Climate Change in a clear and captivating manner.

"13,500 avg users per month for HHS website 23,000 avg users per month for HCS district website" Jason Gaston HCS Communications Director **(above)**



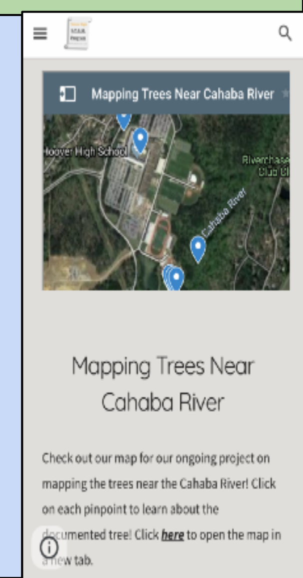
Will do!!

Mon, Nov 25, 2019 at 6:16 PM McClintock, James B <mcclinto@uab.edu> wrote:

> **https://www.al.com/opinion/2019/11/climate-change-in-deep-south-threatens-children.html**
>
> **Hi Janet!**
>
> **Please share this op ed far and wide. Do you know any way to get it distributed across all the students and teachers at all the high schools that attended my recent talk?**
>
> **Thanks!**
>
> **Jim**

Tree Map embedded on the BioBucs website and posted on HHS STEM Instagram (@hooverstem) for community outreach and awareness. Currently we have more than 1400 views.

Dr. M asked us to distribute his OpEd about students & climate change because of the success of the event



PART 4—Results: Evaluate Carbon towers Game & Longitudinal Tree Study

Students really loved the game! It worked well as an introduction, tested on 9th graders, as well as review with upper levels. Approx 60 students played the first version. 50 more will use it during exam review days. Teachers next door emailed about the cheers coming from the classroom. We will need to add some supporting elements to drive the deeper learning. For example, charts showing the sizes of C sinks worldwide and a diagram to create based on group data % C calculations.

Abi and Carson determining tree height. We used Tree Mappers and the GLOBE Phone app to measure the heights of the trees, taking into account the height of elevation, as well as our starting height.

Our tree mapping project was also a major success! In total, we had approx 60 students recording 25 trees. They were all recorded along the river, in the woods, and along power lines as they were easy to access in a short period of time. Each student created a journal to record the data that they found, both the tree height and circumference.
Our Research Team also spent time outside of school recording tree heights and circumference. They will be uploaded to GLOBE.gov. GLOBE is a website dedicated to the collection and assortment of abiotic & biotic patterns around the world. We also recorded the Longitude and Latitude coordinates of each tree so that they could be mapped and re-visited for further investigation.

PART 4—Results: Evaluate Sensor Flotation Device Construction & Data

Vernier GoDirect Sensor: $199

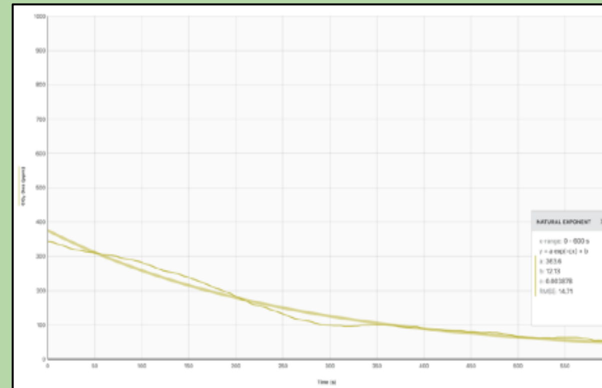
Insulating Foam: $0.60/ft.

Plastic Bucket: $4

Silicone Sealant: $6/10 oz.

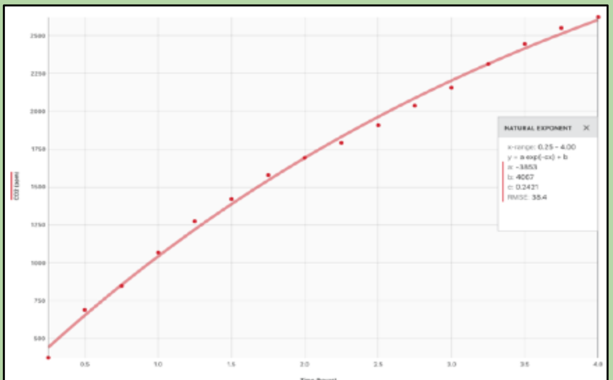
Final Cost: $210.60 or roughly $12 sans the sensor. Note sensors may be available for loan

After successfully completing an extended length test held on the nearby Lake Cyrus, we deemed our vessel a success. Using **Model 2**, we were able to record the CO_2 concentration over the surface of the lake for 4 consecutive hours, at a rate of 4 samples per hour.



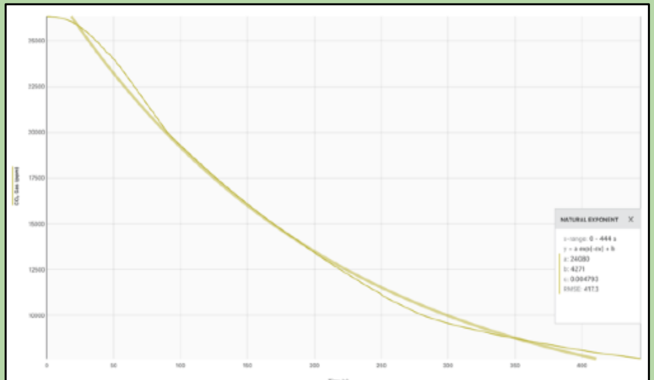
Net CO_2 Release from Ground (10 min, 56ºF, 3:20 pm)

Data collection using ground model. Natural exponential decay shows that the rate of photosynthesis of grass decreases with the amount of CO_2 available



Tracking CO_2 Release from Lake Cyrus (4 hour) (10a-2pm) (moderate temp)

Initial data collection using flotation device model 2. Graph displays a natural exponential relation of the amount of CO_2 released from water over time.

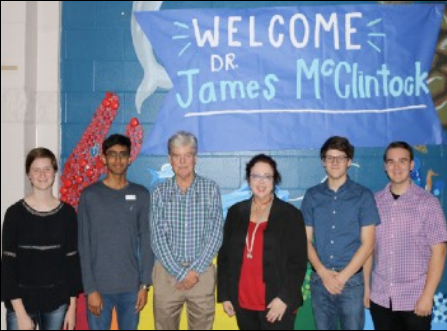


Tracking Return to Atmospheric CO_2 Concentration Equilibrium

Test to see rate of return to equilibrium when CO_2 is exhaled into chamber. Natural decay relationship.

What we Learned:
Recording CO_2 levels displays the natural exponential relations as the rate of CO_2 release/ consumption directly corresponds to the amount of CO_2 available (ppm). Many natural processes display this relation involving euler's number.

PART 5: Project Gallery: Outreach



Noel, Abhi, Dr. M., Ms Ort,Carson, & an APES student **(above)**

A chance to speak w/ a celebrity (Dr. James McClintock)who is changing the world **(Below)**

Flyer for the event with his 2 books **(right)**

From: **The Science Teacher** <onbehalfof@manuscriptcentral.com>
Date: Thu, Oct 31, 2019 at 7:44 AM
Subject: The Science Teacher - Account Created in Manuscript Central
To: <jort@hoover.k12.al.us>

31-Oct-2019

Dear Ms Ort:

A manuscript titled **From Local to Global: Calculating and Appreciating the Value of Trees and Forests** (2019-Oct-TST-F-1823) has been submitted by Dr Nancy Trautmann to the The Science Teacher.

You are listed as a co-author for this manuscript. The online peer-review system, Manuscript Central, automatically creates a user account for you. Your USER ID and PASSWORD for your account is as follows:

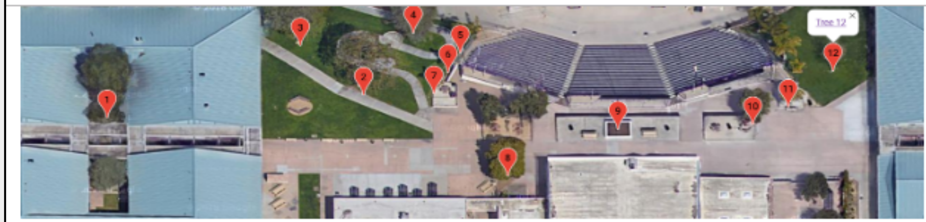
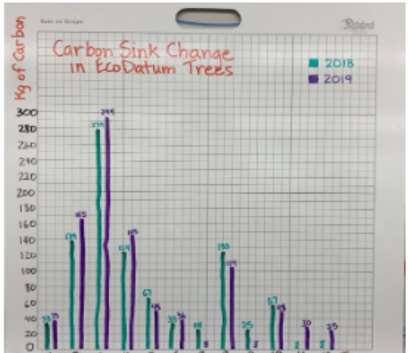


Figure 1. Website used by Santa Maria students to track carbon storage in campus trees.

Evaluate:
To evaluate potential trends in carbon capture on their campus, students create a graph and use the Claim, Evidence, and Reasoning (CER) framework to address the prompt: "How has the amount of carbon stored in the sample trees changed over time?" (Figures 2 and 3). Students reflect on the influence of the local trees they have studied on the microclimate of their area, and how they predict this would change as the trees grow or if they were to be removed.



Carbon sequestration & tree Campus data from partner school in CA. Also one of the co-authors for the NSTA "Science teacher " article **(left & above)**

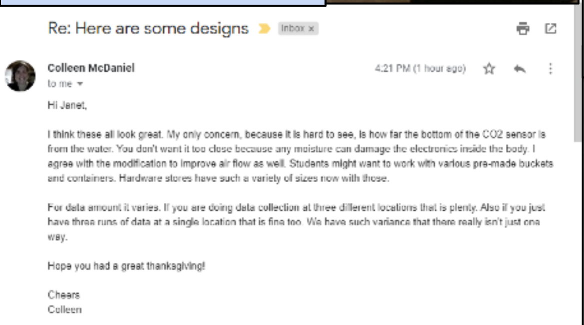
"Science Teacher" submission about using forests, C, and shared data to teach students. This is the group of teachers that will be sharing C / tree mass data from AL to CA. (**Above)**

Students hanging flyers **(right)**

PART 5: Project Gallery (continued)

The STEM Program @ Southern Research Institute helped us print our first 3d device when our printer was not happy (**right**)

Email from Vernier reviewer of our flotation devices. (**bellow**)



Re: Here are some designs Inbox

Colleen McDaniel 4:21 PM (1 hour ago)
to me

Hi Janet,

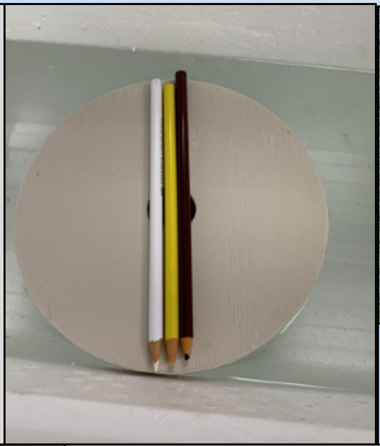
I think these all look great. My only concern, because it is hard to see, is how far the bottom of the CO2 sensor is from the water. You don't want it too close because any moisture can damage the electronics inside the body. I agree with the modification to improve air flow as well. Students might want to work with various pre-made buckets and containers. Hardware stores have such a variety of sizes now with those.

For data amount it varies. If you are doing data collection at three different locations that is plenty. Also if you just have three runs of data at a single location that is fine too. We have such variance that there really isn't just one way.

Hope you had a great thanksgiving!

Cheers
Colleen

We used colored pencil to try and weigh down the printed design in order to test the stability. We need to make sure it would not tip over and get our sensor wet.(**Right)**



A Sensor with a Ginko Leaf, (**above)**

Noel diligently observing the model collecting data over the grass (**above**)

While designing, we ended up using candle wax before acquiring the silicone sealant we now use (**left**).

Another early test of the sensor used a foam bucket filled with water as our water source to compare room CO2 & water. (**right**)

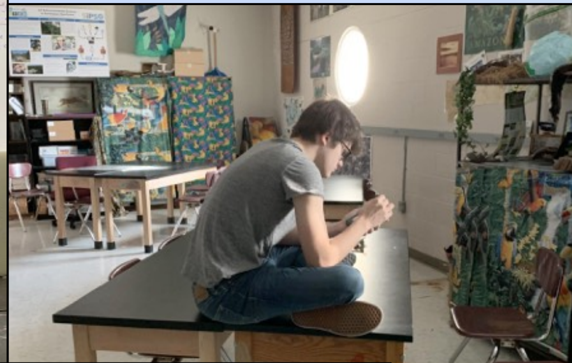
The proof of concept test took place on Lake Cyrus (left), a lake that we plan to investigate further due to its proximity to a major road and housing.

We kept the lab quest in a birdhouse, so no one would disturb it.

The birdhouse and float in action **(above and to the left)**

Errors in the 3D printing of our vessel were aplenty, ranging from dislodgement of the hot plate, needing to find a good balance between flow rate, print temperature, finding the right material, and more (**below**).

PART 5: Project Gallery (continued)

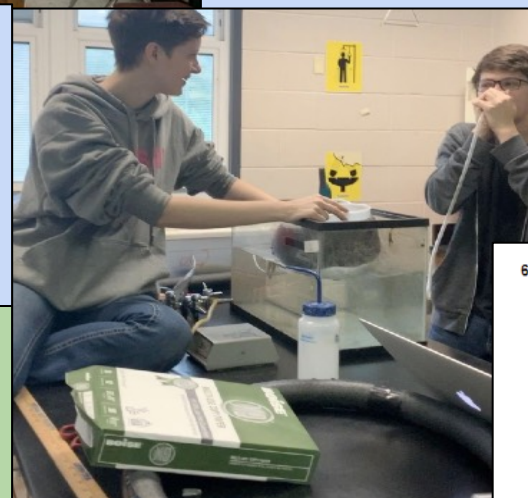


Carson, setting up the LabQuest for a test run. Most data analysis & creativity benefited from table sitting! (**Left**)

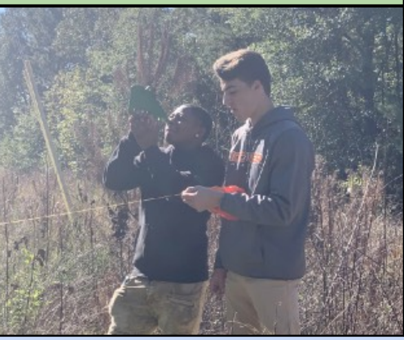
Abi reading the instructions on the tree mapper just to make sure they haven't changed. (right)

"Sometimes the only thing keeping me going is K.K. Slider," -Reid Markland

Our first test for the CO_2 Sensor involved blowing air into a fish tank through a hose to confirm it would record changes in data (**right**)



Year long Student Observation Journal determining trees' locations & mass 50 students monitoring trees from GLOBE Green Down & Tree Protocols **(Below)**

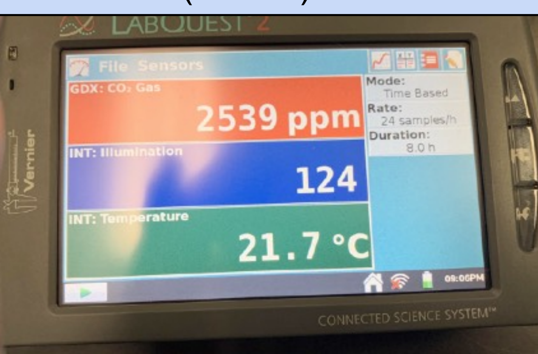


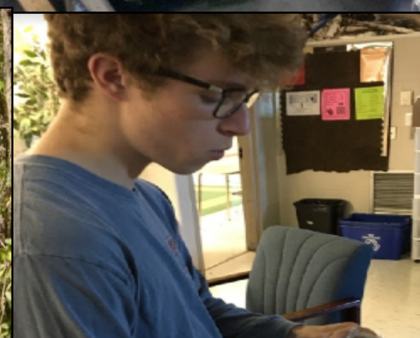
Env Sci students documenting trees **(Left)** Determining Green Down Stage **(below RIght)**

6. Tree Height & Circumference
Evaluate the trees where you leaves are for the below data. We will determine tree height Monday

Picture of Tree	Circum of tree in cm	Your height in cm	Distance from the tree in m/cm	Tree Height	Carbon in Tree Biomass
1	30	188	230		50
2	100	188	850		668
3	40	188	530		80

LabQuest set up to collect CO2 data (**below**)





Reid examining the biochamber to see how our first model could attach to to it. (above)

Noel going higher places to spread the word of climate change, and looking for her team members (right)