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| **Grade**: 9-12 High School Living Env | **Topic:** CO2 and plant density  | **Lesson #** 1 **in a series of** 2 **lessons (subject to change)****2 pds for first part, collecting data in between and plant insertion after week two -- 2-3 pds at the end for analysis/presentation**  | ***Comments/notes*** |
| **Brief Lesson Description**: Explore relationship between CO2 concentrations and plant density by measuring the levels of CO2 before and after plant transfer |
| **Performance Expectation(s): Living Environment Standards** * 5.1a The energy for life comes primarily from the Sun. Photosynthesis provides a vital connection between the Sun and the energy needs of living systems.
* 5.1b Plant cells and some one-celled organisms contain chloroplasts, the site of photosynthesis. The process of photosynthesis uses solar energy to combine the inorganic molecules carbon dioxide and water into energy-rich organic compounds (e.g., glucose) and release oxygen to the environment.
* 7.2b When humans alter ecosystems either by adding or removing specific organisms, serious consequences may result. For example, planting large expanses of one crop reduces the biodiversity of the area.
* 7.3a Societies must decide on proposals which involve the introduction of new technologies. Individuals need to make decisions which will assess risks, costs, benefits, and trade-offs.

**Common Core ELA/Writing/Math Standards*** WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1),(HS-LS2-2),(HS-LS2-3)
* WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significantfor a specific purpose and audience. (HS-LS2-3)
* WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broadenthe inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS2-7)
 | Need to add more common core standards? (Will be analyzing graphs, gathering data, etc.) |
| **Specific Learning Outcomes:** SWBAT analyze the relationship between CO2 and plant density by observing changes that occur to carbon dioxide levels before and after plant implantation.* Students plan for experimentation of how plant density affects environmental variables (such as CO2) by identifying the variables (manipulated, responding, controlled) and making sound scientific hypotheses.
* Students analyze data collected through the use of wireless sensors to support or reject their hypotheses, present their findings/analysis/conclusions, and suggest future improvements that may be done upon the experiment.
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| **Narrative / Background Information**

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| **Background for teachers:*** Will need to prepare plants ahead of time, make sure they are about the same size and release high levels of O2 (as these would probably show more results in terms of CO2 intake)
* Create a closed system -- allow students to determine what kinds of variables to control
* Allot a specific space for the tanks to be where it can be kept for a long period of time and be relatively undisturbed -- if there is a small closet with a window somewhere, would be best
 | **Teacher preparation**: (Plan for 32-34 students) - 8 groups* Closed system -- 1-2 aquarium tanks (use only one if there is one probe; if more than one probe, may add tanks for ability to further validate results); for Vernier, anything that has a 28-30 mm diameter opening to snugly fit the sensor
* Arduino indoor probes or Vernier probes?
	+ Equipment link: [CLICK](https://www.dfrobot.com/product-1023.html)
* Outlet access (check if extension cords/power strips are necessary)
* Plants emitting larger amounts of oxygen
* Test the code that will be used for Arduino functionality - (might be from github) --make additional modifications as needed [esp if testing more variables] -- *this is if Arduino is used; if Vernier, check for Vernier software functionality*
* Students need lab notebooks
* Copies of [lab template handout](https://www.ode.state.or.us/wma/teachlearn/testing/scoring/guides/2011-12/science_inquiry_notebooktemplate_hs.pdf)
 | **Prior Student Knowledge:** * Understanding of applying the scientific method and all of its steps (emphasis on making a scientifically-sound hypothesis, identifying constants and variables in the first part; making conclusions and analyzing data after the experiment)
* Understanding of the reactants and products of photosynthesis and what may happen when these are changed.
	+ Would be helpful if students already understand the concept of cellular respiration as well
* (Before the second lesson)
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| **Science & Engineering Practices:** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.(HS-LS5-7)Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. | **Disciplinary Core Ideas:** LS2.A: Interdependent Relationships in Ecosystems* Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1), (HS-LS2-2)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience* A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2), (HS-LS2-6)
 | **Crosscutting Concepts:** Cause and Effect* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8), (HS-LS4-6)

Scale, Proportion, and Quantity* The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)
* Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

Stability and Change* Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6)
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| **Possible Preconceptions/Misconceptions:** * Confusing the role of CO2 in photosynthesis with the role of O2 (which is taken in and which one comes out)
* May need to guide students in how they change their independent variable -- make sure that they are thinking about possible consequences of changing plant, but provide guiding questions so they figure this out on their own
* Thinking that the CO2 will have to be rapid -- may not be as drastic as they believe (students can clear this up post-experimentation)
 | *Misconceptions about the equipment, experiment, concepts, or vocabulary* |
| **LESSON PLAN – 5-E Model**  |
| **ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:** *These could be in the form of an independent Do Now, pair/group discussion, debate form*Peer-to-peer discussion topics (~10 mins total) 1. Based on your knowledge of photosynthesis, what changes would a highly photosynthesizing plant cause to its environment? (Try to recall the formula)
2. Do you think the air in Central Park would have the same composition/properties as the air by FDR Drive? Explain your reasoning.
3. The atmospheric CO2 concentration is predicted to double within our lifetime. How do you think this will impact the distribution of plant species throughout the world?

**Post-experimentation** opening/engagement activities **(AFTER 4 WEEKS)** (10-15 min total)1. Go around and observe the results from other groups. Decide which plants were the “best” and explain why.
	1. Do a silent vote afterwards.
	2. Receive input as to why
	3. What does “best” mean?
		1. *Students should be mentioning that “better” plants would photosynthesize more and remove more CO2*
2. By that logic, what was the “worst” at doing its job? Why?
 | Are there any videos/interactive resources that students could explore first? |
| **EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:**Lab experimental portion* Students use a provided template **(click** [**here**](https://www.ode.state.or.us/wma/teachlearn/testing/scoring/guides/2011-12/science_inquiry_notebooktemplate_hs.pdf)**)**  to plan out the experimental design (rest of period 1st day - ~ 30 min)
	+ Focus on constants that students will need to control the experiment properly; remind them to keep the independent and dependent variables in mind -- the only thing they can change is the independent variable (plant density)
* Students are told that their group will change one thing about their plants (their tank/chamber may have one plant, another has five plants, one has bigger plants, flowering plants, etc.) -- all other conditions must be kept the same
	+ Allow students to think about this as homework and decide for the next day
* Students briefly explain to me what variables they are changing; ensure that groups have mostly different variables (diff types of plants, sizes, leaf size, house/other) Do Now next day (5 mins)
* **Two weeks must be done without plant implantation -- students insert plants after the first two weeks - DN Week 3**
* Ask clarifying questions about experimental setup, what they will need to check
* *Teacher*: Explain how Vernier probe works, or Arduino 2nd day of first part - About 30 mins total
* Carrying out the lab experiment - (Last 10-15 min of day 2)
	+ Set up apparatus
	+ *Teacher*: check general setup and ensure that apparatus’ are placed somewhere safe with exposure to light for photosynthesisDone throughout the 4 weeks
	+ **Students monitor CO2 levels once a week (about 5-10 min, maybe do now time)** - take notes on what changes they have observed in lab notebooks (Every Friday - 5-10 mins)
 | Allow students to research plants beforehand maybe? Could end day 1 with them filling out the template.Depending on the equipment used, teaching them how to use it to measure CO2 may require more time (if using Arduino, it may require another class pd as they would need a tutorial and time to practice.Could be using an ambient light sensor to ensure that all tanks are receiving the same amount of light.  |
| **EXPLAIN: Concepts Explained and Vocabulary Defined:** **AFTER 5 weeks (Students are given extra week to make a lab report and formal presentation) About 1.5 periods for presentations and discussions***Teacher** Ask for justification behind the results that were seen
* Ensure students relate to the photosynthesis formula

*Student** Individually, students produce lab reports; groups also produce a whole group presentation to show their findings (something that can be observed as a gallery walk, like a poster board)
* Groups present their findings on their individual experiments and provide reasoning based on their independent variables
* Groups compare their findings to that of other groups and explain why the results were different (or not)

**Vocabulary:** carbon dioxide, oxygen, photosynthesis, glucose, chloroplast | *This part and onward will happen after the 4 weeks of experimental data collection, and then after another week for students to create lab reports and presentations.**Maybe do as a gallery walk to save more time?**Will need to make a gallery walk handout for analyzing lab experiments.* |
| **ELABORATE: Applications and Extensions: End of day 2 - finish for HW as needed**Ask students to figure out extensions to the experiment - if using Arduino, how could the other functionalities be used relative to plants? If not using Arduino, students can still use prior knowledge on photosynthesis (and even human impacts on the environment) to relate different environmental factors -- i.e. human pop density and CO2, urban vs rural CO2 levels, etc.* Students work in groups and explain setup and make hypotheses
* Draft experimental setup (only would be missing results, conclusion)
* Peer review other group setups and provide each other with feedback
 | *This part is dependent on which equipment is being used for experimentation.*  |
| **EVALUATE:** **Formative Monitoring (Questioning / Discussion):** *Multiple checks during the lab setup, portion, pre- and post-experiment*1. Ask why we are monitoring CO2 levels, and what changes are expected
2. Ask students how they are properly applying all of the necessary steps of the scientific method (see scientific method template that includes a checklist after every section)
3. Students will be inputting their own observations into their notebook every week
4. Students justify why they believe some plants are “better” based on knowledge of photosynthesis
5. Peer evaluation of extension labs and setup

**Summative Assessment (Quiz / Project / Report):** 1. End-of-lab report with detailed analysis in conclusion and details about extension activities (Individually using collected group data) - students use template from before to write this
2. Whole class presentation by groups on their findings, and comparison to other groups’ findings
 | *During experimentation, during presentations; individual versus group assessment techniques* |
| **EXTEND Further / Reflect: Enrichment: (Added extensions to lesson, if possible)** **Homework Assignment***Have students generate extension questions and discuss/debate*Ex: [Does rising CO2 benefit plants? article](https://www.scientificamerican.com/article/ask-the-experts-does-rising-co2-benefit-plants1/) **-** students can read this and discuss the “benefits” [NY Times: How More Carbon Dioxide Can Make Food Less Nutritious](https://www.nytimes.com/2018/05/23/climate/rice-global-warming.html) Students can find other articles relating these factors and bring in for discussion the following day - **5-10 mins of DN next day - rest of next day will be allotted to new lessons** → Students relate findings to changing climate -- how is having more trees going to affect gas composition? and other student-generated questions | ***Optional*** *- could be done as HW, reviewed as a brief Do Now if time allows*  |