Bay Area Scientists in Schools Presentation Plan

**Lesson Name**  Measuring Carbon Dioxide with Vernier Probes

**Presenter(s)**  Derek Vigil Currey, Ph.D student in Physics at UCB

**Grade Level**  5th  **Standards Connection(s)**  molecules, measurement, breathing and CO₂

**Teaser:** Students will learn about carbon dioxide, how it is put into the air through respiration and removed from the air through photosynthesis, and measure the effects of breathing on carbon dioxide levels using simple tools called probes

**Vocabulary/Definitions:**
- **Probe or sensor:** a device that measures something you’re interested in
- **Respiration (physiological):** process of breathing in air to get oxygen and breathing out waste gases **Respiration (cellular):** process in cells of plants and animals by which sugars are converted into useful forms of energy, releasing CO₂ in the process
- **Photosynthesis:** the process by which plants use water, CO₂, and sunlight to store energy in sugar molecules **Circulatory system:** system that moves blood around the body transporting nutrients and wastes, allowing oxygen to constantly reach different tissues in the body
- **Respiratory system:** system that brings oxygen into the body
- **Atoms:** smallest particle of a substance that has all the properties of that substance
- **Molecules:** a particle of matter made of two or more atoms

**Materials:**
* I will bring:
  - 1 go-links
  - 1 labquest
  - 1 CO₂ probe
  - 1 heart rate monitor
  - digital projector
  - 1 laptop

* The students should have pencil or pens, and a notebook to write in (preferably a scientific notebook)

* I will need a surface to project relevant information.
Classroom Set-up:
- 5 groups of students – it would be good if they were all at a clusters of table
- The room should be able to be made dark for projection (I will bring a digital projector)
- Set up time should be about 5-10 minutes
- Clean-up time should be about 5 minutes as well
- It would be good if the room could be set up so the kids could do some jumping jacks to get their heart rates up for when I talk about carbon dioxide and respiration

Classroom Visit

1. Personal Introduction: 1 Minutes
Derek Vigil – Ph. D student at Berkeley in Physics, interested in doing science education and outreach, in addition to my research on materials of technological interest, i.e. for batteries and solar cells.

Topic Introduction: 5 Minutes
**It is ideal if the student initially aren’t in the room and the probe can be set up to start taking measurements of the CO2 content in the room. Even if the students are in the room initially, the probe should start taking data from about a minute before the presentation starts

Everybody take a deep breath. [model deep breath] Take another.

Raise your hand if you know what happens when we breathe. [should see lots of hands, select student(s): Air comes in and air goes out. [If needed:] How do we benefit from that?
- Take answers, we get oxygen [Write name and chemical symbol on the board.] How many of you already know that? Great!

Breathing is part of a wonderful and more complicated process that all organisms must do called respiration. In addition to bringing oxygen into our bodies to use, we are also releasing another gas: carbon dioxide.

waiting for “respiration”

Why do we need to constantly take in oxygen?
- Take answers, waiting for “because our body uses oxygen and sugars to power itself”

What is released from our bodies during this process?
- Take answers, waiting for carbon dioxide
Write up chemical formula for carbon dioxide, mentioning that it is a molecule made up of multiple atoms (two oxygens and one carbon) – smallest constituents of matter

2. **Learning Experience(s):**

   **40** Minutes

   I have a question for us to explore today: why do we release carbon dioxide? Where is it coming from?

   First, how do we “know” that our body releases carbon dioxide when we breathe? Can you see it? *No, might say they read it in a book.*

   So we need a tool or technique to help us measure gases like carbon dioxide. As modern scientists, we have a device today that can measure the CO2 that comes out of our bodies.

   - Such a device is call a probe, or sensor

   Show the students the **Vernier CO2 probe**

   Describe: The probe works by sending a flash of light from one side of the chamber and through the air to a light sensor, and based on how much light reaches this sensor one can tell how much CO2 is in the air

   Since this probe gives us a stream of data, we can look at the level of CO2 over time. [show students where to read time and CO2 level on the graph] Let's look at the CO2 level data since the beginning of class.

   - Turn on graph showing the CO2 content in the room
   - Show students level at beginning and current level.

   **[If CO2 content has gone up]**

   Can you think of any reason why the carbon dioxide level might have gone up in this room?

   * (most likely) because people entered and were in the room breathing, hence releasing carbon dioxide; interesting idea.

   **[If CO2 content is level or decreased just move on]**

   - If CO2 level goes down, talk about why (maybe people got settled into their seats and stopped breathing as heavily as when they first entered the room)

   Let's see what happens to the CO2 level in the room if we do some jumping jacks, running in place

   - Have everybody get up and do some jumping jacks to get their heart rate up, watch the CO2 levels go up

   - Why do you think the CO2 level went up? *we were breathing harder.*

   - Interesting. Why do you think we were breathing harder? *Might say: needed more oxygen, or something about carbon dioxide.*
We do need more oxygen when we exercise because the muscles in our bodies are working harder. When our muscles work, tiny cells in our muscles break down special stored sugars to get energy. This process is called **cellular respiration**. All living things, including plants get energy for their cells this way.

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy in cells}
\]

Has anyone seen this before? What does this first set of symbols stand for? How about the next symbols? [at end] what does the arrow stand for?

- **sugar** + **oxygen** \(\rightarrow\) **carbon dioxide** + **water** + **energy in cells**
  
  **[cellular respiration]**

So when we exercised, we needed more energy, that meant we needed more oxygen, and hence respiring at a more rapid rate. More respiration = more CO2 released

-This also why you get sleepy sometimes in class, or at church, the build-up of CO2 makes humans sleepy! Why does that make sense? What do we need to break down cellular sugar for energy? **Less oxygen to help us break down sugar for energy**

[If CO2 level showed decrease] Our graph showed a slight decrease in CO2 during the first few minutes of the class. Given what we just discovered, talk about why (maybe people got settled into their seats and stopped breathing as heavily as when they first entered the room)

How do you think plants affect the carbon dioxide level? **Reduce it.** If needed: What gases to plants take in and give off?

Does anyone have any ideas **why** plants might take up carbon dioxide? **To make sugar, photosynthesis**

-Define photosynthesis: plants use CO2, water, and light to make sugars for energy

  **[on Board]** Photosynthesis

  energy from sun + 6CO2 + 6H2O \(\rightarrow\) C6H12O6 + 6O2

  energy from sun + carbon dioxide + water \(\rightarrow\) sugar + oxygen

If this is true, what should happen to CO2 if we put a plant near the probe? **Go down** Let’s test this idea.

Could I get the students in group of 4 and 5, with scientific notebooks out

- I want you to work together to design an experiment where you use the carbon dioxide probe to “see” if we can confirm that a plant is taking in CO2 during photosynthesis
**Instructions for students**

- Draw a picture of what you expect the graph of CO2 v time to look like, and explain why you think
- Think of anything you would need to be careful about in experimental design to make sure that you really are just measuring the effect on CO2 level of JUST plant photosynthesis

Give students 10 minutes to talk about this, walking around to hear what they say. Possible prompts during circulation:
- What do you think the carbon dioxide level will do? How would the graph show that?
- Have you thought about how to design the experiment? What else could affect the level of carbon dioxide besides the plant? How can we isolate our experiment from that factor?

**Share Ideas:**

Let’s come together and talk a little bit about the different ideas people had how to carefully design such an experiment
- Have students raise hands and tell about their experimental design
- Which design seems like it will help us study the effect of a plant on the carbon dioxide level without any other effects clouding our data?
  - Hopefully at least some of the groups will have a plant in a chamber with the probe. If not, try to lead group to putting a plant in a sealed chamber so that no air can get in or out during the course of the experiment

Once the design is out, ask:
- Raise your hands if you know what you expect the graph to look like. Would you come up and draw your idea on the board? [ask another if needed]
- Who else thinks the graph will look like this?
- [Ask someone with hand up] Can you explain why you think it will look like this? *the graph of CO2 v time should be downward sloping with time, since CO2 is being used up by the plant*

Let’s do the experiment
- Put leaf inside of chamber, start taking data with CO2 probe
- Have students watch what happens to the graph with time: with correct plant leaf you should see a pretty noticeable decrease in CO2 level with time. Make sure the leaf is thoroughly illuminated so that it will start photosynthesizing.
- This should excite the students

### 3. Wrap-up: Sharing Experiences 5 Minutes

What happened to the carbon dioxide level in the chamber? *Went down*
Talk among yourselves about why this happened. Can anyone explain to us why the CO2 level went down? [take several answers to get] *into the leaf, plant took it up to make sugar, photosynthesis*
What would have happened if we turned the light off?

What would you expect to see on a graph if we were graphing the amount of oxygen v time during photosynthesis? *It would go up, because the plant releases oxygen during photosynthesis*.

I have a question: Given what we just saw today, why are plants important to our existence?

*Looking for “because they take in CO2 and provide oxygen and sugar, which humans need to survive”*

Right. In fact plants store energy for all living things including themselves, and then break down that sugar in their own cells for their growth using the same cellular respiration we use. [point to formula] But they can take the carbon dioxide produced and use it to make more sugar! The excess oxygen produced in photosynthesis is their waste gas given off by their leaves.

We confirmed today that carbon dioxide is released by humans during respiration and that it is taken in by plants during photosynthesis.

-How did we see this?
  -Wait for answer: “Because we used our probe and saw the CO2 levels went up when humans were breathing a lot, like during exercise, and went down when the plant started photosynthesizing when light was shining on it”

So, we used our probe to measure something that scientists have told us is true, thus becoming scientists ourselves. This is the power of probes, allowing us to do our own experiments and measurements, and do scientific work on our own.

4. **Connections & Close:**

Closing comments: I hope the students learned a lot about carbon dioxide and respiration/photosynthesis today. I hope you saw how you can measure things using probes and learn about the world and nature in a very precise way that allows you to answer specific questions. Science does not just come out of a book but is discovered by smart people like you who are curious enough to go out and test things in the world. Perhaps you can think of more interesting experiments to do with the carbon dioxide probe. If so, feel free to email me and we can talk about it.

**TOTAL 60 Minutes**
Follow-up – After Presentation

Students can feel free to email me at vigil@berkeley.edu and ask me about being a scientist, making measurement, probes, etc.

I recommend Vernier's website (vernier.com) for more information about the probes that are out there and the experiments that can be done with them.