Greenhouse Gases in Dead Run

This document provides intensive instructions for any teacher who wishes to implement "Greenhouse Gases in Dead Run" with their students. We welcome feedback and insights following implementation. If you would like to share your experience with "Greenhouse Gases in Dead Run," please complete this Feedback Form (https://bit.ly/4hw7Jks). We hope you enjoy using "Greenhouse Gases in Dead Run" with your students!

<table>
<tr><td rowspan="3">Estimated total time to complete</td><td colspan="2">Parts 1 & 2: 1 60-minute class period</td></tr>
<tr><td colspan="2">Parts 3 & 4: 1 60-minute class period</td></tr>
<tr><td colspan="2">Parts 5 & 6: 1 60-minute class period</td></tr>
<tr><td>Materials needed</td><td colspan="2">● Slide Deck (Requires modifications for "Local Connections" - make a copy!)
● Student handout (make a copy!)
● Supporting the Science (Reading)
○ Original Text
○ Leveled Text (9th grade)
○ Reflection Questions (Optional resource)
● Digital QOB (Optional resource - make a copy!)
● Dead Run data sets
○ Premade figures
■ Methane
■ Carbon Dioxide
■ Nitrous Oxide
○ or, Google Sheets dataset
● Dead Run Watershed Maps
● Local watershed map (Teacher creates this)
● Internet-capable devices (ChromeBook, iPad, etc.)</td></tr>
<tr><td colspan="3">NGSS alignment</td></tr>
<tr><td>DCI
● ESS2.A
● ESS3.C</td><td>SEP
● Analyzing & Interpreting Data
● Constructing Explanations and Designing Solutions
● Engaging in Argument from Evidence</td><td>CCC
● Cause & Effect
● Stability & Change
● Patterns</td></tr>
<tr><td colspan="3">Student outcomes</td></tr>
<tr><td colspan="3">● Students will analyze data collected from "real world" research taking place in Baltimore, MD to identify patterns, trends, and investigative questions.
● Students will understand relationships between urban activities, stream gas concentrations, and critical zone processes.
● Students will develop and communicate scientific claims citing evidence identified during data analysis and the scientific principles that connect the evidence and claims.</td></tr>
<tr><td rowspan="2">Recommended prior learning</td><td colspan="2">UCZ Data Lesson: An Introduction to the Critical Zone</td></tr>
<tr><td colspan="2">Familiarity with the biogeochemical cycles</td></tr>
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Background information for teachers:
The Critical Zone (CZ) is the relatively thin layer of the planet where interactions occur between the biosphere, hydrosphere, geosphere, and atmosphere. These interactions are vital to the maintenance of healthy ecosystems and the existence of life on Earth. The CZ includes everything between the deepest groundwater all the way to the tops of the tallest tree canopy (from bedrocks to treetops).

Key functions of the Earth's CZ include:

1. Water Cycling
    a. Water plays a central role in nearly every CZ process.
    b. The CZ controls the flow of water through ecosystems.
    c. The CZ regulates water's quality and availability.
2. Soil Formation and Maintenance
    a. Rocks and minerals are broken down through the process of physical, chemical, and biological weathering.
    b. Plants, microbes, and animals help break down organic matter to recycle nutrients and mix soil layers.
    c. Water carries dissolved minerals and nutrients through the soil.
3. Carbon Storage
    a. Soils and vegetation are important sites for carbon storage.
    b. Soil stores more carbon than the atmosphere and vegetation combined (second in active storage only to the ocean). SOURCE
    c. Vegetation (especially old growth forests) also stores carbon through the process of photosynthesis.
4. Ecosystem Supports
    a. All life exists in the CZ - from the smallest microbes in the soils to the tallest trees in the Amazon Forest.

Scientists and researchers around the world are studying the CZ to better understand how it responds to both natural and human changes. The study of the CZ involves interdisciplinary collaboration between scientists from a range of disciplines, including (but certainly not limited to) geologists, hydrologists, ecologists, engineers, and sociologists.

Video: Explore the Critical Zone (https://youtu.be/8gW-Vy7zFdU?feature=shared) WSKG Public Media

Greenhouse Gases in Dead Run: Instructional Outline

Part #1: The Opener (15 minutes)

1. Objectives: Get students interested/engaged with the lesson's topic.
2. Outline of suggested delivery
    a. Cold Open: Independently, students brainstorm ideas to the prompt: "**List some ways that urban activities might influence the critical zone.**"
    b. Offer the students one of the following:

i. Multiple samples from various local water sources, labeled and in a sealed clear jar
ii. A collage or picture presentation of local water bodies from the community.
iii. This compilation of urban streams.

c. Students answer the question "**List some ways that urban activities might influence streams.**"
   i. First individually, then turn and talk with a partner.
      1. They may reuse some of the responses from their original lists
   ii. Ask each pair to share one of their responses.
      1. Instructor creates a list on the board, OR
      2. Student pairs come up and write their response on the board
   iii. Have the students read the list and ask if there are any other ideas that they didn't share, but think are really important that they want to add.

d. Present or draw the students' attention to two samples of water that look similar (both are relatively "clear") but are from different sources - one urban the other not, or much less so.
   i. If you were unable to collect your own samples, consider showing them this image.
   ii. Student pairs respond to the prompt "**In what ways could these two samples of water be different?**" Brainstorm a list of at least 3 ideas with your partner."
      1. The objective is to get students to think about the "invisible" contents of bodies of water.
      2. Each pair shares one idea with the class.
      3. If none of the pairs brings up gas content, instructor should ask leading questions to get students thinking about gases in streams.
         a. e.g. "How are fish able to live under water?" → Oxygen gas in the stream.
      4. For each of their 3 ideas, student pairs think of ways urban activities could influence those factors.

e. Introducing the next segment - student groups will be given stream data for concentrations of CO_2, CH_4, and N_2O as well as the N_2:Ar ratio for Dead Run, a stream in Baltimore County, MD.
   i. In pairs or small groups, ask students to brainstorm everything they know about these gases: Where do they come from (sources)? Where do they exist in the critical zone (nutrient cycling, rock cycling, etc.)? Do they have any particular connection to urban or human activities? How might the presence (or lack of) these gases influence the ecology of a stream?
      1. Optional: Consider assigning each group a different gas and completing this as a jigsaw activity.

Part #2: Digging into Data (45 minutes)

1. Objectives: Give students an opportunity for hands-on data analysis and to form initial impressions of the "data story".
2. Outline of suggested delivery
   a. Before instruction, determine the best method of delivery for the data sets:
      i. Option #1: Allow students to investigate the data using raw datasets (make a copy) and the CODAP platform (requires internet connection and student device).
         1. CODAP is a relatively intuitive platform and allows students to easily manipulate different variable presentations within a single dataset. It is

recommended that you have students complete a CODAP tutorial prior to beginning this lesson, if you choose this option for data delivery.
        a. You can establish CODAP files to share with your students that have text, tables, graphs, etc. already loaded for them to work with - as long as you/they have a school-supported Google Drive
    2. This option allows students to have a richer experience in manipulating the data they are working with.
  ii. Option #2: Use these premade figures.
    1. Carbon Dioxide
    2. Methane
    3. Nitrous Oxide
  iii. Option #3: Instructors can use the Google Sheets version of the data sets and CODAP (or another data visualization program) to create additional subsets of data for each variable to be presented as premade figures to the students.
b. In the same pairs or small groups, students will inspect the data in order to 1) identify trends & patterns, and 2) generate questions they have about their observations and the data set at large.
c. At the end of the data investigation, each group will record their observations and questions in a class Question Observation Board (QOB)
  i. Poster or flip-chart paper, students record their observations and questions on post-it notes
  ii. Digitally using premade Google Slides, Padlet, or similar collaboration space.
d. Facilitate a discussion in which:
  i. Students look for similar themes among their observations and/or questions → visually arrange these so that they share a space in the QOB
  ii. Students generate any additional questions that they think about during the discussion.

Part #3: Supporting with Science (30 minutes)

1. Objectives: Provide students with the information they need to support their understanding about the data.
2. Outline of suggested delivery
    a. Before instruction, determine the best method of delivery for the supporting science for this activity:
      i. Option #1: Mini-seminar or lecture
      ii. Option #2: Guided reading
        1. Could assign each group a different section of this reading and complete this as a jigsaw activity.
        2. This reading is leveled into a second version of text, rated a 9th grade level on the Flesch-Kincaid Readability Scoring scale. If your current students are at a lower reading level, consider a text levelling tool such as Magic School to help modify the text.
      iii. Option #3: Other - you know your students best!
    b. Students explore deeper understanding/learning through the instructor's preferred method.
    c. Instructor facilitates class discussion in order to:
      i. Match what they have learned to their observations and questions in the QOB
        1. If students use the reading, here is a list of suggested questions that you can ask students to help them process what they have read, and further the discussion.

ii. Inventory the observations and questions still left unexplained or unanswered on the QOB.
    1. Ask students to brainstorm what they still need to know and how they might find or collect that information.

Part #4: Digging Deeper (30 minutes)

1. Objectives: Continue to support understanding and a deeper analysis of the Dead Run data by allowing students to explore additional resources.
2. Outline of suggested delivery
    a. Students are provided with additional information about Dead Run and work in pairs or small groups to try to explain or answer the remaining observations and questions in the QOB.
    b. In pairs or small groups, students work together to complete a claim-evidence-reasoning (CER) to respond to the prompt "**In what ways do urban activities influence streams?**"
        i. Alternatively, you could:
            1. Ask students to complete the CER individually and collect as a formative assessment.
            2. Allow pairs or small groups of students to create the claim and evidence statements together, but then ask students to complete the reasoning statements individually and collect as a formative assessment.

Part #5: Local Connections (30 minutes)

1. Objectives: Connect the students' learning to local and familiar phenomena.
2. Outline of suggested delivery
    a. Before instruction, find or create maps of the school neighborhood or community that feature a stream. Include labels of well-known or familiar places and landmarks to help students find their bearings.
        i. Google Maps in various layer modes can be useful for this type of activity.
        ii. Ideally, the stream should have its headwater in a relatively un-rural landscape and then pass through urban/developed land areas. If you cannot find a stream that meets these criteria, consider looking for two streams - one in a highly urbanized area, one in a more rural area.
    b. Provide students (individually, in pairs, or in small groups) the opportunity to investigate the map(s). Students will try to brainstorm ways that they could study the stream(s) in order to determine whether the urban activities in their community are having similar impacts as seen in the Dead Run datasets.
        i. Students should work to develop a hypothesis that would guide their proposed study.
        ii. As additional extension activities, students could:
            1. Plan an investigation.
            2. Plan and carry out an investigation (extension of planning an investigation) - based on the resources available to you.
            3. Consider policy recommendations for urban planners, public works departments, gas and oil companies, etc. citing the Dead Run data to support their proposals.

Part #6: Conclusion (30 minutes)

1. Objectives: Synthesize student learning by building consensus through group discussions.
2. Outline of suggested delivery

a. Students respond to the lesson summary prompts.
    i. Students write individually first.
    ii. Students meet up with their partner or small group to share answers and prepare a unanimous group response to the prompts.
    iii. As each group shares out their responses, the instructor will facilitate conversations to build shared conclusions about the Dead Run datasets, the data's implications, and the relevance to or impact on the critical zone.
b. Summary prompts:
    i. How do CO_2, CH_4, and N_2O enter and move through the critical zone, and how might urbanization alter their natural cycling?
    ii. What patterns or trends did you observe in the greenhouse gas data from Dead Run, and what do these patterns suggest about how urban activities influence stream chemistry?
    iii. What evidence from the Dead Run dataset best supports the claim that urban activities impact greenhouse gas concentrations in streams?
    iv. Based on what you learned from the Dead Run data, how might urban activities in our own community be affecting local streams? What evidence would you look for to investigate these impacts?