Kids Into Discovering Science: A Framework for Place-Based, Hands-On Ecology

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Curriculum Overview

I. Introduction

Kids into Discovering Science (KiDS) is a K-12 science education program designed to bolster academic achievement and critical scientific thinking. Through 10 in-class hands-on lessons and a field day trip, students activate biological curiosity and engage in hypothesis testing. In KiDS, elementary students act as the "Principal Investigators" on their own plant ecology experiment. Students develop hypotheses, collect data, and test their hypotheses by calculating and graphing results. The program culminates in a full day of hands on activities on the field day led by college undergraduate and graduate students in ecology, evolution, plant science, and entomology.

Participating in hands-on science through experimentation is one of the most-effective ways to engage young people in science[1]. But many teachers face challenges when it comes to inquiry-based science programming[2] , and teachers often find it difficult to coordinate hands-on, outdoor activities to supplement classroom learning[3]. Similarly, undergraduate and graduate students in scientific fields need opportunities for outreach and experience translating science beyond the academy[4,5]. The Kids into Discovering Science (KiDS) curriculum offers a synergistic outreach opportunity to students and science enrichment to elementary school students through 10 weeks of in-classroom short lessons and a field trip to a local natural area.

The mission of the KiDS curriculum is to 1) promote academic achievement in a low-income and under-served school district by giving students firsthand field and lab experience with science and scientists; 2) engage students in science as a process of discovery and questioning, not simple memorization of facts; 3) provide opportunity for students to realize a “sense of place” by focusing on the ecosystems that make their home landscape unique; and 4) provide an opportunity for undergraduate and graduate students and faculty to increase their skills at science communication and outreach of their expertise beyond the academic forum. Each lesson is designed to address all of these goals: lessons are written so that a wide variety of volunteer instructors can come to meet with the elementary students, and content focuses on principles of ecological understanding and the scientific process within local environments.

The KiDS curriculum was designed and implemented by University of California, Davis, scientific researchers for an under-served elementary school, Lower Lake Elementary, near the University of California McLaughlin Natural Reserve, in Lake and Napa Counties, CA. The authors worked with elementary school teachers to identify curriculum needs a priori. The science, technology, engineering and math (STEM) topics included in the program were highlighted by the classroom teachers as areas in which they need the most support. The program has been implemented annually by UC Davis graduate students and faculty since 2010, and has each year served 50-90 5th graders, 2-3 5th grade teachers, 10-20 parent chaperones, 20-25 graduate students (2 as program co-coordinators), 5-10 undergraduates and 3-6 faculty members.

Though the curriculum was originally written to focus on the landscape of Lake County, California, and McLaughlin Reserve in particular, the curriculum can be adapted to other schools and other landscapes while preserving its mission and much of its structure and content. Many lessons can already apply to other landscapes and experiments with minor tweaks, while others may require more creativity. See part IV of this overview and "Adapt This!" boxes throughout the curriculum for more on this topic.

III. Curriculum Overview

Instructed by university scientist volunteers, the elementary students in the KiDS program receive 10 weekly 60-90-minute lessons designed to teach plant biology, ecology, and the scientific method, followed by a field trip to a local reserve that reinforces concepts from the classroom lessons. Our curriculum is a series of "live" working lesson documents that are revised and commented on by volunteers as they teach them each season.

In the classroom lessons, each class runs a two-month long experiment testing the effects of soil type on plant growth. For Lower Lake students, we chose to focus on a unique local soil type, serpentine soil, so that students can learn about their home environment while developing scientific skills and knowledge of ecological concepts. The experiment serves as the foundation for lessons on plant growth, ecology, soils, graphing and statistics. At each classroom lesson, a group of 2-4 volunteer instructors introduce themselves (including their pathway to science, their goals, and their scientific interests), review the experiment so far, and introduce that day's lesson. Volunteer instructors guide the lesson with the aid of prepared SmartBoard materials. Students take notes, answer questions, make written and visual observations, record data, and make graphs in a workbook provided to each student.

Lesson 1 introduces the program, explores the scientific process, and introduces students to observation using habitat photos. In Lesson 2, students set up their experiment. Lessons 3 and 4 focus on principles of plant growth and introduce data collection and bar charts. Lessons 5 through 9 introduce students to several ways of assessing, visualizing, and summarizing results, including graphing and calculation of basic summary statistics. Lesson 10 reviews previous topics and asks students to apply what they have learned through a fun Jeopardy!-style game. A final, optional lesson features the expertise of a volunteer instructor; we provide a lesson on wildfire from 2016 as an example here. Each lesson is designed to be highly interactive. Students discuss, ask questions of each other, and formulate hypotheses, and work in groups to address their hypotheses with measurements and analyses.

The students deepen the ecological significance of what they have learned in lab study during a field day to a local natural area. Students are divided into small groups led by volunteer instructors. At the reserve, the small groups engage in activities designed to give them first-hand experience with ecology, including awareness of key scientific concepts: biodiversity, evolution, and climate change. Students get to observe principles learned in the classroom up close in a local landscape. Students rotate through 3-4 different stations, including a natural history hike, a hands-on station with locally collected aquatic invertebrates, a food webs activity, and re-enactment of a real experiment focused on predator-prey relationships and camouflage.

IV. Curriculum Documents

Curriculum documents include the overview, the classroom lesson plans, a field trip lesson plan that includes several stations, and the student workbook. Each classroom lesson document includes an overview cover sheet that describes the themes, activities, and necessary supplies, the lesson plan, and assessment materials for volunteers. SmartBoard materials referenced in the lessons are provided for most lessons as a separate document.

- Curriculum Overview
- Student Workbook
- Lesson 1: California Habitats
- Lesson 1 SmartBoard Documents
- Lesson 2: You Are The Scientist!
- Lesson 3: Scoring Emergence
- Lesson 3 SmartBoard Documents
- Lesson 4: What Do Plants Need To Grow?
- Lesson 4 SmartBoard Documents
- Lesson 5: Evaluating Success
- Lesson 5 SmartBoard Documents
- Lesson 6: Seeds and Seedlings in Action
- Lesson 6 SmartBoard Documents
- Lesson 7: Visualizing Plant Growth With Graphs
- Lesson 7 SmartBoard Documents
- Lesson 8: Which Group Is Taller, On Average?
- Lesson 9: Jeopardy!
- Lesson 9 SmartBoard Jeopardy! Board and Documents
- Lesson 9A: #ActualLivingScientist Mini-Lesson
- Special Feature Lesson: Fire in the Environment
- Special Feature SmartBoard Documents
- Field Trip Lesson Plan

V. Benefits for Students, Teachers, and Volunteer Instructors

The relationship established between volunteers and the students and teachers in Lower Lake provides many benefits to all parties involved. Our program meets many Next Generation Science Standards and Common Core State Math Standards and for 5th grade, as well as similar grade levels. We meet these standards by asking questions and conducting investigations focused on plant growth, interaction between organisms and their environment (plants and soil), and the relationship between humans and the environment. Students learn how to classify objects such as plants and soils. They develop testable questions, plan and conduct simple investigations, identify variables, select appropriate tools to carry out experiments, record data, draw conclusions, and innovatively work towards developing a report of their results through classroom sharing and comparing of information.

In addition, the focus on local soil types in the central experiment, the use of local habitats as examples, and the field trip to a local reserve under the guidance of scientist volunteer instructors also allows students to develop a "sense-of-place" and understanding of local ecology. There is room in each lesson to develop students' sense-of-place by learning about the immediate environment and how each lesson is related to the local landscape. Discussing with students their observations, hypothesis, experiment design, and results allows for the connection to how plants and soils behave in their local ecosystem.

Important to our program and Lower Lake Elementary School is the ability to also present students with a different perspective of who is a scientist and what type of work they are involved in. Lower Lake elementary school is recognized as an underserved and low-income elementary school, and it is located in a rural area. As a result, students have few opportunities to interact with scientists and the examples of scientists that they do see are likely to fit stereotypical models of a scientist, making it difficult for students to see themselves as future scientists. By bringing in a wide variety of volunteers, we showcase diversity in science and demonstrate that science is for everybody and that there are many ways to be a scientist. In 2017, we added a new lesson focused specifically on highlighting our volunteer staff and diverse scientists from around the world at work in the lab or field.

The teachers in Lower Lake have indicated that they need the most support in teaching STEM subjects. In the KiDS program, volunteer instructors work with classroom teachers to introduce STEM concepts into the classroom. In turn, teachers use their own expertise to help newcomers to teaching bring their scientific knowledge into a 5th grade classroom, emphasizing concepts, managing the classroom, and maintaining the experiment throughout the week when volunteer instructors are not present. Volunteers develop skills at communicating science to non-scientist children, teachers, and parents. They also engage in multiple facets of elementary education including curriculum development, instruction, and assessment.

VI. Tailoring and Adapting the Curriculum

Location and Experimental Focus

A fundamental part of our program is its incorporation of place-based ecology, posing a challenge to those wishing to introduce the KiDS curriculum to schools outside of Lake County or where serpentine soils are not present. However, the curriculum can be tailored to other locations without losing the importance of local ecology by modifying the experiment to use local soil types or even designing a completely different experiment. Throughout the curriculum, "Adapt This!" boxes provide suggestions for adapting that lesson's content to different contexts. For example, the first lesson on habitats can use photos of any habitats. A plant growth project works the best with our existing curriculum, but many lessons (e.g., observing habitat photos, calculating averages, visualizing data with graphs) are easily adaptable to a variety of systems.

Instructor Type

A main goal of the program is introducing students to real scientists and science pathways. In the KiDS program, we have used a rotating team undergraduate and graduate science students, faculty, and staff as volunteer instructors to present the curriculum, with minimal responsibilities for the full-time classroom teachers outside of formal program time. Volunteer instructors describe their field of study to students and use examples from their work to emphasize concepts in the curriculum. Volunteer instructors are invited to design lessons or field trip stations based on their area of expertise. Past lessons of this type have focused on nematodes found in soils on the school grounds and fire ecology in Lake County in the year after a major local wildfire. The strength of this setup is the opportunity for students to meet many scientists and science students and in turn provide science outreach opportunities for students and faculty. The major drawbacks are a lack of consistency in instructors and mixed teaching ability in the teaching team.

This curriculum may be taught instead by full time teachers or by a more even balance of classroom teacher/volunteer time. If the program is taught by full-time classroom teachers, we encourage teachers to invite scientists into the classroom as guests and to use Lesson 9A to emphasize diversity in science and science careers, which we consider a key part of our program. Teachers can look into the Skype A Scientist program (https://www.skypeascientist.com/) to find teachers who are interested in virtual classroom visits.

Student Age or Grade Level and National Education Standards

Though the KiDS program was aimed at children in 5th grade, the overall structure and many of the lessons can be adapted for older or younger students. Workbook prompts can be made simpler or more complex. For younger students, the program can focus on observation and a simplified experimental process (removing concepts such as photosynthesis, graphing, and averages). Older students can work on more complex experiments and pursue greater depth in the topics of plant science, the experimental process, and scientific careers. Older students can also design their own individual or small group research projects (look into PlantingScience (https://www.plantingscience.org/) for online mentorship support for small group projects). Other options for older students include interviews or research about real scientists, explorations of relevant scientific literature, keeping observations in a less structured lab and field notebook, and presenting final reports on their research.

This program was designed for 5th graders in California, and the lesson plans highlight Next Generation Science Standards for elementary school and Common Core math standards for 5th grade. Instructors wishing to address Common Core literacy standards in the sciences might add readings relevant to the central experiment, such as articles highlighting similar experiments performed by professional scientists, or articles highlighting the local environment. The overall structure of using a plant science experiment or other experiments to demonstrate the scientific process from experimental setup through data analysis and presentation can be adapted to meet a wide variety of basic and advanced topics in life and earth science, measurement, and statistics. See Education Standards section of this overview and Adapt This! boxes for more ideas.

VII. Common Core Math and Next Generation Science Standards:

Below are Common Core Math and Next Generation Science Standards, organized by grade level, that are directly addressed by our curriculum, as well as those standards (*in italics*) that are partially addressed or may be addressed through supplementing the curriculum with additional relevant grade-appropriate activities within the overall KiDS program structure. Below each standard we list particular lessons that cover this standard or where a standard may be met with some adjustment. At present, this curriculum is not sufficiently focused on reading or writing to meet Common Core English Language Arts standards. However, the experimental framework, logbook, and sense-of-place journal could be used as a starting point for reading and writing exercises related to the experiment, local environments, relevant scientific literature, and other topics covered in this curriculum.

Kindergarten—

NGSS

K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

(Lesson 4)
K-ESS3-1. Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live.

(Lesson 1, Fire Lesson, Field Trip)

Common Core
CCSS.MATH.CONTENT.K.MD.A.1. Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.

(**Lessons 3-5)**

CCSS.MATH.CONTENT.K.MD.A.2. Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference.

(Lessons 3-5, 8)

Grade 1—

NGSS
N/A

Common Core

CCSS.MATH.CONTENT.1.MD.C.4. Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another.

(Lessons 3-8)

Grade 2—

<u>NGSS</u>

2-LS2-1. Plan and conduct an investigation to determine if plants need sunlight and water to grow.

(Full program, modified for younger students)

2-LS4-1. Make observations of plants and animals to compare the diversity of life in different habitats.

(Lesson 1, Field Trip)

<u>Common Core</u>

CCSS.MATH.CONTENT.2.MD.A.1. Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.

(Lessons 4-7)

CCSS.MATH.CONTENT.2.MD.A.2. Measure the length of an object twice, using length units of different lengths for the two measurements; describe how the two measurements relate to the size of the unit chosen.

(Lessons 4-7)

CCSS.MATH.CONTENT.2.MD.D.9. Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems[1]using information presented in a bar graph.

(Lesson 3)

Grade 3—

<u>NGSS</u>

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

(Full experiment, Lesson 1, Fire Lesson, Field Trip)

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.

(Full experiment, Lesson 1, Fire Lesson, Field Trip)

<u>Common Core</u>

CCSS.MATH.CONTENT.3.MD.B.3. Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs.

(Lesson 3, Lesson 7)

CCSS.MATH.CONTENT.3.MD.B.4. Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units— whole numbers, halves, or quarters.

(Lessons 4-7)

Grade 4—

<u>NGSS</u>

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

(Lesson 4, Lesson 6)

<u>Common Core</u>

CCSS.MATH.CONTENT.4.MD.B.4. Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Solve problems involving addition and subtraction of fractions by using information presented in line plots.

(Lesson 7)

Grade 5—

<u>NGSS</u>

5-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.

(Lesson 4)

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water.

(Lesson 4)

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

(Lesson 4, Fire Lesson)

Common Core

CCSS.MATH.CONTENT.5.MD.B.2. Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Use operations on fractions for this grade to solve problems involving information presented in line plots.

(Lesson 7)

Middle School NGSS

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

(Lesson 4)

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

(Full experiment)

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

(Full experiment, Fire Lesson)

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

(Fire Lesson, Field Trip)

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

(Field Trip)

Middle School Common Core

Grade 6—

CCSS.MATH.CONTENT.6.EE.C.9. Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation d = 65t to represent the relationship between distance and time.

(Lesson 7, Lesson 8)

CCSS.MATH.CONTENT.6.SP.A.1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

(Lesson 5, Lesson 8)

CCSS.MATH.CONTENT.6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

(Lesson 5, Lesson 8)

CCSS.MATH.CONTENT.6.SP.A.3. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.

(Lesson 5, Lesson 8)

CCSS.MATH.CONTENT.6.SP.B.4. Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

(Lesson 3, Lessons 7-8)

CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context.

(Lesson 5, Lesson 8)

Grade 7—

CCSS.MATH.CONTENT.7.SP.B.4. Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations.

(Lesson 8)

Grade 8—

CCSS.MATH.CONTENT.8.SP.A.1. Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

(Lessons 7-8)

CCSS.MATH.CONTENT.8.SP.A.2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.

(Lessons 7-8)

High School—

<u>NGSS</u>

HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

(Lesson 4)

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

(Fire Lesson)

<u>Common Core</u>

Many standards within the following categories in Statistics & Probability:
Interpreting Categorical and Quantitative Data

Making Inferences and Justifying Conclusions

VIII. Lesson Plan Glossary

- **Volunteers or volunteer instructors –** the UC Davis graduate and undergraduate student volunteers that teach in the KiDS program at Lower Lake Elementary and the McLaughlin Reserve.
- **Students –** 5th grade program participants
- **Sense of Place Connection –** Themes of the lessons that build student's sense of their place and interaction with ecology and biology. This connection is built in each lesson in different ways through both the curriculum and additional material presented by the specific volunteers for that class period.
- **Teachers –** 5th grade class full-time teachers
- **SmartBoard –** A digital interactive whiteboard used in the Lower Lake classrooms.
- **Student Experimental Log –** A set of handouts, datasheets, and worksheets that we provide for each student in the program with materials for each lesson. These have been provided as a bound, printed softcover and as copies organized in a 3-ring binder. The Student Experimental Log pages specific to each lesson included at the end of that lesson plan. Also referred to as "Experimental Log."

IX. Acknowledgements

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Lesson 1: California Habitats

Overview & Guiding Questions

Learning about local habitats gives us a unique opportunity to become scientists in our own way. Students identify similarities and differences among photographs of soils and habitats. They make a connection between soil attributes and differences in the plant assemblages that make up habitats.

- What do scientists do? What are the steps of the scientific method?
- What is a habitat?
- What are the differences between plants in each habitat?
- What causes differences between habitats?

Time Required

60 minutes

Preparatory Activities

- Print habitat photos if needed.

Supplies

- Habitat photos (printouts for students and SmartBoard file)
- Experimental logs (needed for all subsequent lessons)

Classroom Activities

Volunteers introduce the KiDS program and give an overview of the next 10 weeks. Next, volunteers lead a class discussion of what scientists do and the elements of the scientific process, emphasizing observation and asking questions as first steps. Then, students make observations about photos of local California habitats and soils. The lesson finishes with a class discussion of how habitats differ from one another and what causes those differences.

Objectives

Ecological Understanding

- Students will be able to describe the concept of a habitat.

Scientific Process

- Students will be able to describe elements of the scientific method.
- Students will understand what an observation is and practice making observations of local habitats.
- Students will compare and contrast observations of different habitats and soils.

Sense of Place

- Students will be able to describe key characteristics of soils and plants in three California habitats. They will use key words to describe differences and similarities among the various soils, plants, and habitats. Students will articulate how these concepts relate to their immediate environment.

LESSON PLAN OUTLINE

I. INTRODUCTION (20 MIN)
II. COMPARING HABITATS AND SOILS (30 MIN)
III. WRAP-UP (10 MIN)

LESSON PLAN

I. <u>INTRODUCTION (20 MIN)</u>

- **Objective: Introduce ourselves and the program, describe what's in store for them, and explain why we are doing this.**
  a. *Welcome to the KiDS program! This program is all about introducing you to the scientific process in a fun and exciting way.*

  b. *First we'll conduct our very own experiment, led by you! You will all become scientists, leading an experiment to answer questions about plants and soils. Over the next couple of weeks you'll learn why we collect data and how to collect data yourselves. Then you'll learn how to use data to answer questions you might have. Near the end of the program, we'll go out to a nearby nature reserve where you will bring your investigations outdoors into the real world. Spend a few minutes introducing yourself and what you study.*

  c. *What is a scientist?* Discuss the student's ideas about scientists and their jobs. Describe the different parts of the scientific process – observations, hypotheses, gathering data, analyzing the data with math, sharing results…

  d. *Okay, so I mentioned that we are going to be doing an experiment. What do you think an experiment is? Why do scientists do experiments? You scientists – the class – will be doing an experiment with plants. What are some reasons that we might want to study plants?* (Ans: food, clothing, shelter, medicine, oxygen, etc.).

  e. *Many plants and animals are not found everywhere. Sometimes certain types of plants and animals will always be found together in similar environments. We call the type of environment that each plant and animal prefers its "**habitat**". Today we're going to talk about different habitats and* *the plants that grow in these habitats, and ask you all to think about how these habitats differ.*

f. *We're also going to talk about **soil**, which makes up part of the habitat where plants live. Soil is the upper layer of the earth where plants grow, made up of rock, minerals, and decaying parts of plants and animals.*

II. COMPARING HABITATS AND SOILS (30 MIN)

a. Have students organize into pairs (the teacher chooses pairs prior to this lesson, total of about 16 pairs per classroom).
b. Go through the content of the Student Experimental Log with the students. Show the students the log page and the pictures they will be using for this lesson.
c. Put the photos up on the SmartBoard and tell the students the names of the habitat and soil types. Have the students write these down in the spaces in their notebooks. Explain that these habitats have different plants and different soils. Explain that we want them to look at the photos and to find at least three similarities and also three differences among them. Point out that they can describe color, types of plants, colors of flowers, numbers of plants, etc.
d. In pairs, students spend 10 minutes comparing the 6 different photos. They should pay close attention to what the plants and soils look like in each habitat. Students should have log questions 1 – 4 filled out by this point.
e. Lead a whole class discussion of differences in habitats and soils, with students following along with the questions in their experimental logs. The goal is to help the students think about soils as a reason for differences in communities by asking the students if they think the differences in soils are related to the differences in habitats. (Key to Soil and Habitat Names: Photo #1: Grassland Soil, Photo #2: Oak Woodland Soil, Photo #3 Serpentine Forest Soil Photo #1: Native Grassland, Photo #2: Blue Oak Woodland, Photo #3 Jeffrey Pine Forest)

Adapt This!

- Use photos of local soils and habitats in place of these photos.
- If possible, choose soils and habitats that either play a role in your experiment and/or that students will see on the field trip.
- Choose habitats that are easily compared and contrasted--make sure that they are not too similar or too different.

f. Use the following guidance questions to help direct class discussion. All students should write down the answers in their logbooks (Page 4, Question 5).

   i. What is different about the habitats? (Possible answers: plants look different, there are more plants in some than others, they differ in size, type (ie. trees versus flowers) and in color, different weather may indicate different climates in these places)
   ii. What is different about the plants in these habitats? (Possible answers: some are trees, some are bushes, some are grasses and flowers)
   iii. What do you think causes different plants to grow in different habitats? (Possible answers: temperature, rainfall, interactions with animals or other plants, influence from people, soil. Make sure to include soil in the discussion. Ideally, the students to will name soils as a cause on their own, but they may need to be guided. Help students consider things plants need to grow (water, sunlight, nutrients) and where those things come from.)
   iv. Similarly, discuss the differences between soils (Possible answers: color, rock content, texture, apparent moisture, visibility of clear layers). Invite students to speculate about how soils became different (Possible answers: climate, what the soil is made of, how old it is, plants and animals living in the soil, topography).

III. WRAP-UP (10 MIN)

Wrap up the class. Tell the students what they will be doing next class! We are actually going to investigate how these different soils might relate to the different habitat types! Emphasize that this is “real” science that scientists like us do! Explain that they will be observing soils in class and coming up with their research question to test in an experiment. Try to get them excited about what is next and clearly connect it to the observations they made today.

Assessment for Lesson 1

Team/Student Name(s): ________________________________Date: _____________

Level of Understanding **Indicator**	**Engaged** 1 points	**Emerging** 3 points	**Proficient** 6 points	**Total Points** (0 = no answers)
Scientific Skill Development: [Questions 1 & 3 (if created by students, not copied from the key*), 2, 4, 5a, 5d]. Student's power of observation and perception are growing. *1st class was allowed to create names, so consider any descriptive words they used as observations; 2nd and 3rd classes were given names from a key to copy down, so do not include these in the scoring	Student uses vague words ("it", "better", "different colors") instead of specific words in descriptions	Specific descriptions ("rocky", "tall", "trees", "soil") are given for habitat and soil pictures. If the student uses both vague and specific descriptions, round up the scoring.	Student makes comparisons for habitat pictures or soil pictures using specific words ("taller", "red versus brown colors").	
Ecological Understanding:	Student just repeats	Student begins	Key words used by instructors: Climate, erosion, vegetation,	

(Questions 5b, c, e) Student articulates causes of differences in soil and their relationship to habitats.	observations.	making connection between soil and plants in a habitat to soil, or tries to explain differences vaguely ("different places", "weather")	animals. Student articulates that soils have an influence on how and where plants are grown which in turn influence a habitat. Or makes references to climate ("temperature, rainfall") and geology on the formation of soils. Or makes a connection between soil types and their respective habitats	

Lesson 2: You Are The Scientist!

Overview & Guiding Questions
Students will be provided with samples of two soil types and record observations of differences and similarities between them. They will develop an experiment to continue exploring the connection between soil characteristics and plant growth.

- What is soil? What do you see in your soil?
- What do plants get from the soil and how do they get it?
- Do all plants need the same things?
- Why use an experiment?

Time Required
90 minutes

Supplies
- Broom and dustpan
- Crushed granite
- Schoolyard soil
- Jeweler's loupes
- Paper plates
- *Classroom setup:* 1 light apparatus (PVC frame, 1 light bulb, timer and extension cord), 2 trays for holding pots
- *Experiment kits for student pairs:* 2 4-inch pots, 2 coffee filters, 2 bags of soil, 2 packets of seeds, 2 labels

Preparatory Activities
- Make sure each classroom has a complete kit with all supplies.
- Collect soil from the schoolyard the day of the lesson. Soil should be collected so that it includes as much "live" material as possible (e.g. root bits, leaves, soil fauna, etc.). If time allows, collect soil with students prior to the lesson.
- Place soil material on paper plates. Each team should be given a plate with loam soil and a plate with serpentine soil.

Classroom Activities
Students will touch, smell, and see different root bits, leaves, soil fauna, and non–living material in two soil types. Then, student pairs will plant seeds in each soil type and begin an experiment. Students will continue to examine the characteristics of the different soils and will connect these characteristics to plant growth. They will create hypotheses and predictions related to plant growth for their experiment.
NOTE: Experiment setup requires many hands. At least 3 volunteers recommended.

Objectives
Ecological Understanding
- Students will be able to describe basic components of soil.
- Students will begin to describe how soil influences plant growth.

Scientific Process
- Students will practice making observations with multiple senses.
- Students will practice asking scientific questions.
- Students will be able to formulate a hypothesis making a prediction about their experiment.
- Students will be able to describe basic elements of experimental design.

Sense of Place
- Students will examine soil samples taken from their local environment.

LESSON PLAN OUTLINE

I. WHAT IS SOIL, LOOK AT IT! (15 MIN)
II. WHAT IS THIS EXPERIMENT AND WHY ARE WE DOING IT? (15 MIN)
III. EXPERIMENT SET-UP (45 MIN)
IV. WRAP-UP (15 MIN)

LESSON PLAN

1. **<u>WHAT IS SOIL, LOOK AT IT! (15 MIN)</u>**

Objective: To start making observations. Notice that soil is complex and has many components, including rocks and plant materials (bits of leaves, roots). Students may observe living organisms in the soil.

Prep: One or more volunteer puts soil on paper plates while the other gives the introduction. Each team gets one small handful of soil and one handful of crushed decomposed granite.

> **<u>Adapt This!</u>**
> Use local soils gathered near the school for this section.

a. Review Lesson 1, focusing on observation and its role in the scientific process.
b. *What is soil?* Get some ideas from students and list on the board. Guide students to the definition of soil as a mixture of rocks, minerals, and organic material (decaying plants and animals) that forms the upper surface of the earth and where plants grow. Soil also includes air, water, and living plants, animals, fungi, and bacteria.
c. *Before scientists can start asking questions, they make observations.* Hand out the paper plates with soil and jeweler's loupes or magnifying glasses.
d. *Let's spend some time exploring the soil on our paper plates. Take a few minutes to look at it, feel it, and smell it.* Have students record their observations on page 5 of the Experimental Log.
e. Give students 5 minutes to observe the soil and then discuss as a group. *What does the soil feel like, what does the rock feel like?*
f. *What do you see in your soil samples?* Create a list or Venn diagram on the SmartBoard; the list might include small rocks, leaf litter, plant roots, and live insects.

g. *Do you see anything in your crushed rock samples? What don't you see here in the soil that you think you might see in a different sample or at a different time?*
h. *What does your soil smell like? Does it smell differently than the crushed rock? Why do you think it smells differently? Why does garbage smell? Why do feet smell? These things all smell because they have bacteria – little tiny microorganisms – living in or on them. The bacteria take bits of living matter and break it down into smaller bits in a process called decomposition. So, soil smells because there are living things in it that are decomposing organic matter, like the plant roots, for example.*
i. Come back to the definition of soil following observation, and guide students to a working definition of soil (may include: contains rocks, minerals, water, air, decomposed living things, live plants or animals, medium for plants to grow, covers the earth surface, etc.)

2. **<u>WHAT IS THIS EXPERIMENT AND WHY ARE WE DOING IT? (15 MIN)</u>**
Objective: Recognize that plants are immobile and therefore very dependent on the conditions in their immediate environment, especially the soil their seed landed on. Begin to learn what plants get from soil.
    a. *Okay, so I mentioned earlier that we are going to be doing an experiment on plants. We just had you explore soil because it's an important part of the plant's environment. Based on what you have learned today and in Lesson One, what kinds of differences could you see in the different soils that you looked at in photos and in person?* Have the students look at the photos from Lesson One.

<u>Adapt This!</u>

- Modify the experiment to fit your local environment by choosing local soil types to compare and contrast.
- Set up your experiment with other types of treatments, such as different watering protocols.
- Design your own experiment from scratch that reflects the unique features of your students' local environment. Your experiments can involve plants, animals, or something else. Plant and soil science experiments work well with all of the lessons, including Lesson 3 (emergence), Lesson 4 (how plants grow), and Lesson 6 (seeds). Experiments that track growth over time or another measureable feature over time can work well with parts of Lesson 5 (comparison), Lesson 7 (graphing) and Lesson 8 (calculating averages).

b. *How might the soils be different? How might they be different in a way that matters to plants?* Possible answers: may have things that plants need (water, nutrients) or things that hurt them (toxic substances, animals), some soils may be easier to grow in (less rocky).
c. *What do plants get from the soil? What kinds of things do they need? How do they get things from the soil?*
   Answers: plants need sunlight, water, nutrients, and carbon dioxide. Plants take in water and nutrients from the soil through their roots and plants use these to make their food (we'll come back to this in more depth in Lesson 4, but introduce the idea that soil provides some but not all of what a plant needs).
d. *Do you think all plants need exactly the same things in the same amounts? Why or why not?*
   Answers: Most plants need the same main ingredients, but they differ in how much and where they get these things from.
e. *We're going to explore these questions in our experiment, which will be to look at the effects of two different soils on plant growth. Beans will be planted in a loamy soil and a serpentine soil. We'll watch them grow over the next few weeks and take measurements so that we can compare their growth later.*
f. *Scientists use experiments to answer questions about their environment. What do you think we are asking with this experiment?* (Ans: how do different soils affect plant growth?). Which soil do you think plants will like more? Less?
g. *We can restate our question as a hypothesis, which is simply a question that can be answered by doing experiments and collecting data. How would you state the hypothesis?*
h. Work with students to come up with possible hypotheses (e.g. Soil A will have taller plants, soil B will have taller plants, they will be the same). Emphasize that hypotheses are specific ("grow taller" not "grow better") and include explanation ("I think X will happen because Y"). *We'll use our experiment to test our hypothesis. Please write your hypothesis on the first page of your experimental log so that we can think about it throughout the experiment. If we have additional hypotheses as the experiment progresses we can add them to this page.*
i. As we start getting experimental results we'll go back and check our hypothesis and see what we have learned about it.

3. **EXPERIMENT SET-UP (45 MIN)**
   Prep: Hand out one student kit unit to each team. Have one volunteer demonstrate the potting procedure so the students can follow along.
   a. As a class, go though all the articles of the kit.
   b. Have students place the coffee filter at the bottom of the pot.
   c. Pour the bag of soil into the pot, being careful not to lose any. The paper plates from the soil observation could be placed under the pots to catch any loose soil. This may make for easier clean up after potting is finished.
   d. Slowly pour the vial of water over the pot, giving the soil time to soak it up (this may need to be done outside – or, have one KiDS volunteer go around to each pair and pour water into the pots)
   e. Place all ten seeds in the pot and gently press them into the soil. Leave an inch or so of distance between each seed.
   f. Place the label in the pot (write down the soil type on the label. In previous years, the white labels were for loam soil.)
   g. Put the pot anywhere in the tray under the light fixture located on a table somewhere in the classroom.
   h. Repeat for second pot.
   i. Clean up stations and wash hands
   j. Observe as one KiDS volunteer sets up the lighting system and adds water to the tray.

4. **WRAP-UP (10 MIN)**
   Objective: Have Students speculate on what might happen in the experiment. Recall that soils are different from each other and have different components, many of which are important for plant growth. Give a hint of what we'll do next time.
   a. *Do you have any predictions for what might happen? Will some plants grow bigger than others? Which ones?*
   b. *When do you think these seeds will start to emerge? Do you think that beans in different soils might emerge at different times? Will they all emerge? Or will some just die or stay in the soil?* Pairs discuss, then document predictions about that in the experimental log in the binder.
   c. *When the seeds start emerging you will start collecting data on how many plants emerge in each soil. Any predictions? What kind of data do you think you need to collect?*

Assessment for Lesson 2

Team/Student Name(s): _______________ Date: ________________

Level of Understanding **Indicator**	**Engaged** 1 points	**Emerging** 3 points	**Proficient** 6 points	**Total Points**
<u>Scientific Skill Development:</u> (Questions 1-3) Student's power of observation and hypothesis building is growing.	Student predicts that plants will grow differently in different soil types.	Student specifically states how plants will differ in each soil type (e.g. taller/shorter, faster/slower, etc.)	Student offers an explanation of how or why the differences in plant growth might occur.	
<u>Ecological Understanding:</u> (Questions 2, 3) Student can identify soil as being made up of many living and non-living things and relate it	Student accurately predicts which soil type will better support plant	Student explains why plant growth is different in different soil types. (e.g. more/less water or	Student correctly relates differences in plant growth to differences in soil characteristics.	

to testing plant growth.	growth.	nutrients in one soil type).		

Lesson 3: Scoring Emergence

Overview & Guiding Questions

Students make their first observations on plants grown in two different soil types by tracking seedling emergence in each pot over the week after planting. They continue by visualizing their data by making bar charts.

- What is emergence and why would we measure it?
- What are some factors that cause differences in seedling emergence in the pots?
- How can we count the seedlings that are emerging?
- What is a bar chart and why would we use one?

Time Required

50 minutes plus an additional 10-20 minutes over one week for scoring emergence.

Preparatory Activities

Make sure emergence videos are on flashdrive or that there is internet access to view videos via Youtube.

Supplies

- Colored toothpicks to mark first 3 emergents
- Example charts and graphs for SmartBoard
- Emergence videos on flashdrive or links to videos

Classroom Activities

Students make descriptive observations of their newly emerging plants and discuss emergence and soil differences. Students then turn their descriptive observations into quantitative observations and plot their emergence data on a Plant Emergence Chart.

Objectives

Ecological Understanding

- Students will be able to describe emergence and identify emergence as part of plant growth.
- Students will describe some reasons why emergence might be different in different soils or among individual seedlings, such as competition and emergence.

Scientific Process

- Students will be able to record emergence data in a bar chart.
- Students will begin to gain familiarity with reading and creating charts and graphs.

Sense of Place

- Students begin to observe how plant growth is different in different local soil types.

LESSON PLAN OUTLINE

I. INTRODUCTION (10 MIN)
II. WHAT'S GOING ON IN OUR POTS? OBSERVATION AND DISCUSSION (15 MIN)
III. SCORING EMERGENCE, INITIAL SESSION (20 MIN)
IV. SCORING EMERGENCE REPEATELY 3-4 MORE TIMES (5 MIN)
V. LESSON SUMMARY (5 MIN)

LESSON PLAN

I. INTRODUCTION (10 MIN)

a. Review conversations from the wrap up from lessons 1 and 2.
What experiment did you set up last week and what were your hypotheses? What do we think might happen to the different seeds that we planted in different soil types? What kinds of data should we collect on our pots to answer those questions?
b. Define emergence: **the appearance above the soil of a newly germinated plant**. Show videos on flash drive or on YouTube (many videos demonstrating emergence can be found online; a good one can be found at <https://www.youtube.com/watch?v=1-Z1etoGp0Q&spfreload=10>).
Ask students to call out "Emergence" when they see it occur on the video.
c. *Do you think all of the seeds will emerge? Why or why not?* Possible answers: (competition, soil content)
d. *Do you think the seeds in the different soils will take the same amount of time to emerge? Why or why not?*
e. *Why is emergence important? Why would we want to measure this?* Possible answers: It's the first step in plant growth and competition—if a plant can't germinate and make it out of the soil surface, then it has no chance to grow and compete above the soil. It has already lost the competition just because soil conditions weren't right.

II. WHAT'S GOING ON IN THE POTS? (15 MIN)

a. Do observations in groups for 5 minutes in the Experimental Log (page 6).
Observe your pots and write and draw what you see. Are seedlings emerging? Are they all the same size? Shape? Are they different colors? Are they different heights? Do they have different numbers of leaves? Does this depend of the type of plant, or type of soil?

b. Students use three different colored toothpicks to mark the first **three** emergents in each pot. Count the number of seedlings that have emerged in each pot, and the number of leaves on the first emergent. Note this number in the Plant Emergence Datasheet (page 20 of the students' experimental log), and write any other observations you notice about the seedlings. Attention: This datasheet is a primary part of the assessment for this lesson.
c. *Why we would want to mark our plants?* Answer: To identify and keep track of individual plants.
d. Class discussion about what they are observing in each pot. Write group observations on board. Share with the class how many seedlings emerged in each pot.

III. SCORING EMERGENCE (15 MIN)

a. *We will score how many seeds have emerged at several times over the next couple of weeks to track how many seeds emerge and how fast they emerge. This is how we'll keep score! Instead of simply recording these numbers, we're going to plot them on a chart so that we can visualize how seeds emerge over time.*
b. *What are graphs and charts used for?* Possible answers: organizing information/compare and contrast.
c. *What are some charts or graphs you are familiar with?* Show graphs and charts that they may or may not be familiar with on the SmartBoard (pie chart, bar chart, line graph, histogram).
   d. *Each person has two copies of a handout called the "Plant Emergence Chart" that we will make the chart on. These are on pages 22 and 23 of your logbooks. The kind of graph we will make is called a bar chart. A bar chart is used to graph the number of things that are counted over different categories, in our case, different dates. The vertical line on the left is the Y-axis (draw this on the board). This axis represents the number of emergent plants that we see in a pot. The X-axis is the line at the bottom of the page. It is*

Adapt This!

The section on introducing types of graphs, why scientists use them, and creating bar charts to track quantities over time can be used for a wide range of experiments, not just plant growth experiments. For example, Instead of tracking seedling emergence, you could track emergence of butterflies from pupa using a similar chart.

marked with the different dates that we are going to observe our pots.

e. *Let's start by marking today's data for one of the pots on a chart on the board.* Use one team's pot as an example, call on them and ask how many plants they have in their pot. Mark the top square on the graph on the board that corresponds to that team's number of emergents, and then fill in that bar.

f. *Each group will do the same thing for the number of plants that you have your pots. Each group will have two bar chart, one for the serpentine pot and one for the loam pot.*

g. *We'll continue to record emergence throughout this week. We'll do this over the next couple of days.* We recommend that emergence is recorded in the classroom by students and teachers on each Monday, Wednesday, and Friday before volunteers arrive.

h. Note on completing the bar chart: the easiest way to record emergence is to do it as a bar chart, with total emergent seedlings in the pot on each date, and an increasing total over time. Alternatively, older students can make a histogram instead, which makes it easier to see when most plants are emerging. In comparison to the bar chart, a histogram would reflect new emergent plants in the most recent time interval, not total emergence on that date (for each measurement day, subtracting the prior measurement day from the total), so that each bar reflects the proportion of germinants in each time interval. Whether you choose a bar chart or histogram, give examples and be clear and consistent.

4. SCORING EMERGENCE REPEATEDLY 3-4 SESSIONS (5-10 min each)

a. *Teams will observe the number of emergents 3-4 more times in the next two weeks. At each "sampling date" you will record the number of new plants that have emerged on your team's* ***datasheet*** *and* ***bar chart****.*

b. Discuss the schedule of data collection for the next couple of weeks with the teachers. This can be either pretty independent, done as 5-10 minute projects in between other activities, or can be done with the whole class and examples on the board, as the students' abilities and classroom time allow. It is recommended that a volunteer or volunteer coordinator email the teacher's weekly or more to remind them of this.

5. LESSON SUMMARY (5 MIN)

a. Briefly go over new key terms learned in this lesson (emergence, serpentine soil, loam soil, different types of charts: bar, line, t, pie, competition)

b. Show second video. Have students call out "emergence" when they see it. Choice of videos available online include the following:

Link 1:
<https://www.youtube.com/watch?v=eDA8rmUP5ZM&index=5&list=PLghRKyA3-GgV9OE-uGQjhP9V0dymYBVeK>
Link 2:
<https://www.youtube.com/watch?v=iFCdAgeMGOA&list=PLghRKyA3-GgV9OE-uGQjhP9V0dymYBVeK&index=6>

Assessment for Lesson 3

Team/Student Name(s): ________________ Date: ________________

Level of Understanding **Indicator**	**Engaged** 1 points	**Emerging** 3 points	**Proficient** 6 points	**Total Points**
Scientific Skill Development: (See Plant Emergence Chart pg. 21-22) Student is beginning to visualize their observations in a quantitative form.	Student/team created: 1) Bar chart does not accurately reflect the number of emerged plants. Missing data AND numbers on x-axis)	Student/team created: 1) Bar chart reflects number of plants per pot accurately in the y and x-axis for both serpentine and loamy soils. (Can be missing either some data OR numbers on x-axis)	Student/team created: 1) Bar chart reflects number of plants per pot accurately in the y and x-axis for both serpentine and loamy soils 2) Accurately labeled the plant names and soil types. No missing data, accurately labeled days since planting on x axis.	
Ecological Understanding: (See Seedling Emergence worksheet pg. 6) Students are developing an understanding on	Student/team made: 1) Minimal/ unclear observations of seedling emergence.	Student/team made: 1) Key observations of seedling emergence (emergence #) emergence.	Student/team made: 1) Key observations of emergence in both serpentine and loam soils (emergence # and at least one other observation)	

soil effects on plant growth based on qualitative observations made for plant emergence in serpentine and loam soils.				

into discovering science

Lesson 4: What Do Plants Need To Grow?

Overview & Guiding Questions

Students gain an understanding of the role of water, sunlight, carbon dioxide to make glucose, water, and oxygen and where plants obtain these things. Students will develop a systematic method for measuring plant height and will articulate if these data support their hypothesis.

- What do plants need to grow?
- How do they get these things and what do they use them for?
- How do we figure how plants are getting what they need?
- How would you measure plant height?

Time Required

80-90 minutes

Preparatory Activities

None

Supplies

- Rulers
- Stakes
- Twist ties
- Scissors
- Toothpicks in three colors
- Paper plates
- SmartBoard documents

Classroom Activities

Students will work as a class to discuss what plants need to grow and how plants use their leaves and roots to access the ingredients needed for growth. Students learn how these ingredients for growth are combined to help the plant make food through photosynthesis. Students then develop methods for plant height measurement collection and maintaining plants and take their first measurements. Finally, students will make the connection between their initial data recordings to their hypothesis.

Objectives

Ecological Understanding

- Students will be able to describe the basic elements of plant anatomy (leaves, stem, roots) and how a plant uses these structures.
- Students will be able to provide a basic definition of photosynthesis and identify the ingredients and products of this process, as well as how the plant accesses the ingredients.
- Students will be able to articulate how competition may limit growth of plants and why thinning their pots is useful.

Scientific Process

- Students will practice taking measurements using a consistent method.
- Students will use metric units to measure and be able to describe why they are using centimeters rather than inches.
- Students will practice careful recording of data and checking their recording for completeness and accuracy.

Sense of Place

- Students begin to gather data in an experiment based on local ecology.
- Students discuss factors that affect plant growth in their region.

LESSON PLAN OUTLINE

I. WHAT DO PLANTS NEED TO GROW AND WHERE DO THEY GET IT FROM? (20 MIN)
II. SEEDLING DATA RECORDING (5 MIN)
III. MEASURING SUCCESS AND EXPERIMENT MAINTENANCE (25 MIN)
IV. PROVIDE SUPPORT FOR TALL PLANTS (IF NEEDED) (10 MIN) (May not need to do this yet)
V. OBSERVATION JOURNALING AND DISCUSSION (5 MIN)

LESSON PLAN

I. WHAT DO PLANTS NEED TO GROW AND WHERE DO THEY GET IT FROM? (30 MIN)

a. *Recall the list of things we came up with for what plants need to grow (Lesson 2).* Volunteers write the list on the board as students brainstorm. The list should eventually include sunlight, carbon dioxide, water, and nutrients. Bring up the plant diagram on the SmartBoard (or draw a basic picture of a plant). Then, as a class, label the plant parts (roots, leaves, stem) and discuss where each item from the "what plants need" list comes from (sunlight/energy from the sun, carbon dioxide from the air, and water and nutrients from the soil), which parts of the plant are used to access each item (leaves for sunlight and carbon dioxide, roots for water and nutrients). Write each item into the diagram next to the appropriate plant part. Students should follow along in their Experimental Log, labeling the plant diagram. If there is enough time, students may be asked to write out longer answers to the questions on the next page.

Adapt This!

- This lesson will work well for any plant growth experiment.
- The photosynthesis introduction works well as an introduction to plant measurement but can stand on its own as an introduction to photosynthesis.
- The photosynthesis lesson pairs nicely with the optional wildfire lesson--these could be paired up in a pared down version of the curriculum.

b. **Note on NGSS 5-LS-1:** One of the NGS standards requires that students understand that plants get the materials they need for growth "chiefly from air and water", with an emphasis on the idea that the material for plant matter comes mostly from air and water, not the soil. This comes from a misunderstanding that plants "eat" soil. The trickiest part of this concept is that plants do absorb most of their water through the soil (and by many definitions, that water *is part of* the soil) and do get nutrients that are essential to growth from the soil. To meet this standard, take care throughout this section to emphasize the importance of carbon dioxide and water as the "ingredients" in photosynthesis, while nutrients from the soil are tools (like kitchen tools) that help the process along. You can also address the misconception directly, noting that soil is not the plant's "food"—the plant makes food using ingredients in air and water.

c. Project blank photosynthesis equation onto SmartBoard (three boxes for "ingredients" and three boxes for "products." *Ok, so now we know the items that plants need for growth, but how do they use those things?* The answer we're looking for is that plants use those things to make food in a process called photosynthesis. Have students repeat this term, and write it on the board.

d. *What kind of food do plants make? All living things are made up of three main ingredients: carbon, oxygen, and hydrogen, so that is what most of our food is made of, too. We eat other living things (plants and animals) to get these. Plants need carbon, oxygen, and hydrogen, too—but they make theirs from scratch, using carbon dioxide (carbon and oxygen) and water (hydrogen and oxygen) as ingredients, and sunlight as a tool (kind of like we use an oven as a tool to make our food). Nutrients are also tools that help the plant grow—like measuring cups, they help make photosynthesis happen but are not ingredients.* <u>Fill out the left side of the photosynthesis equation boxes together (carbon dioxide + water + sunlight). Students should fill out the corresponding page in their notebooks.</u>

e. *The food that plants make is called glucose, which has carbon, hydrogen, and oxygen in it. Photosynthesis also gives off waste products, (just like we don't use every part of our ingredients when we cook—we have eggshells and peels left over). In photosynthesis, these products are water and oxygen.* <u>Fill out the right side of the photosynthesis equation boxes together (glucose + water +oxygen). Students should fill out the corresponding page in their notebooks.</u>

f. *Why is photosynthesis important?* Connect photosynthesis explicitly to plant growth (plants build their bodies by making glucose), as well as other ways it is important to global ecosystems (providing oxygen, biomass for habitats, food source for animals, plant matter for wood, paper, etc.). Students should then write a sentence or two discussing why photosynthesis is important below the equation.

NOTE: It can be a good approach to explain parts II & III together before handing out the plants and rulers. Marking emergence is very fast, and only a few students will need to thin right now, so it's good to get them started on measuring. Write a list on the SmartBoard of the three things the students need to do: 1) Measure Emergence, 2) Thin if necessary, then mark with toothpicks 3) Measure your plants. If you choose to do these parts one at a time, DO NOT hand out rulers until students have been instructed in how to measure the plants.

II. <u>SEEDLING DATA RECORDING AND THINNING (10 MIN)</u>

a. *We're going to start working with our plants. First, take emergence data on them as you did last week. You'll have 5 min, and then we'll move on to thinking about other ways to record the success of plants in these pots.*
b. Have each pair collect their pots from the tray.
c. Measure emergence in both pots and record the data in your Plant Emergence data sheet.
d. *If it looks like pots are getting crowded with plants, the plants will need to be thinned. It is necessary to remove some of the plants in order for the three we are studying to be healthy. If there are too many plants they can end up competing with each other for resources and even killing each other, and we don't want that to happen!* Mark the three healthiest looking plants with toothpicks. Then cut other plants at the soil level until there are three plants remaining (cut all plants that are not marked with the toothpicks). There should be three plants left after thinning. If students have three or fewer plants, they should mark as many plants as they have and do no thinning. We do not want to pull the plants out of the soil because that will disturb the roots of the plants we want to grow. Explain these the purpose of this process to the students as many will not want to remove any plants from their pots. (Hand out scissors AFTER explaining this and reiterating: "Cut until there are three plants left").

III. <u>MEASURING PLANT SUCCESS AND EXPERIMENT MAINTENANCE (25 MIN)</u>

a. *How do we as scientists figure out how well plants are doing, or if they are getting all of their needs met? Do you have some ideas about how we might tell* *which plants are getting more of what they need and which ones are not getting enough?*

b. *We can measure plant height as a basic way of looking at how well plants are growing and how fast. Plants that are getting sufficient nutrients, light and water will grow faster and taller than those that do not. You are going to take height measurements over the next couple of weeks, and build another graph. We can use these measurements and the graph to compare how plants grow on the different soil types.*

c. *How would you go about measuring plant height?*

d. *First, before we measure heights we have to check out our tools. Take a good look at your rulers. Notice that they don't actually start at zero! What do we need to do about this?* Show the students how to gently push the bottom of the ruler into the soil so that the "0" line is at the soil level and you start measuring from the base of the plant [show picture on board]. Be careful not to harm your plants!.

e. (Make sure to finish describing methods before handing out the rulers! Only hand them out when students are ready to begin measuring right away).

f. Explain our methods for height measurement: place ruler at the soil, gently hold the top of the plant (the top of the <u>stem</u> not the leaves) to measure its longest height. Each student should <u>record</u> this by writing down the protocol (the method we used to measure height; each student should make sure that measurements are taken correctly and are accurately recorded) as their answer to the first question on page 10 of the experimental log. Make sure to write everything down so you will remember and repeat exactly what you did.

g. <u>Note the color of the toothpick for the plant being measured and record this value on your Plant Growth Datasheet. All heights should be measured to the nearest 0.1 cm</u> (students may not understand this as they are just learning decimals, explain by drawing a ruler on the board). Be sure to record the height for the correct toothpick color. We will record them later on charts in another lesson.

h. *How would height be measured on a different species (e.g. tree versus grass)? Are there differences that we need to consider? Plant may be of different shapes that we need to take into consideration.*

i. *After you are finished measuring, make sure you have to described/drawn your measuring methods in as much detail as possible so you can remember next time!*

IV. PROVIDE SUPPORT FOR TALL PLANTS (IF PLANTS ARE READY FOR SUPPORT, 5 MIN)

a. To stake plants gently:

   i. Carefully place stakes in the soil about 1-2 cm from the base of the plant to avoid damaging plant roots.
   ii. Tie a twist tie to the stake about 7-8 inches above the soil. (Demonstrate and diagram this on the board).
   iii. Make a loop around the plant that is at least the size of your thumb. This will give the plant a little bit of room and will support it without damaging the stem. *What would happen if ties were too tight on the stem* (plants would wilt or break)? *Why is that?* (Stems transport water, nutrients and air throughout the plant).
   iv. If you finish staking your plants before everyone else, you can move on to answer the other questions in your experimental log.

V. OBSERVATION JOURNALING AND DISCUSSION (10 MIN)

NOTE: This lesson is very busy. If there is very little time, focus on the last question about the hypothesis.

a. Spend five minutes answering the rest of the questions on page 4 and 5 of the Experimental Log. *If you can't think of a way to write the answer, you can draw the patterns that you saw*.
   i. Did all the seedlings emerge on the same day? Can you describe the pattern of emergence?
   ii. Did one pot have more seedlings emerge than others? If so, what do you think caused the difference?
   iii. Did all of the seedlings in each pot look the same? Or do you observe difference between them?
   iv. Did any of the first three plants that emerged from the soil (the ones that you gave toothpicks to) die? What do you think we should do if one of these plants dies? Have students move the toothpick to the next closest plant and make a note of this in their experimental log.

b. *Let's go back to your <u>hypothesis on **Page 5** of your Experimental Log</u>. What were some of your hypotheses? Do we have any information that you can use to address these hypotheses? What other kinds of information will be needed to answer them?* Be careful to note that we have just started the experiment, and that we need more data before drawing conclusions. *Our limited data at this point (or even at the end of the experiment) can't "prove" your hypothesis, but it can be evidence!*

Assessment for Lesson 4

Team/Student Name(s):__________________ Date: __________________

Level of Understanding **Indicator**	**Engaged** 1 points	**Emerging** 3 points	**Proficient** 6 points	**Total Points**
Scientific Skill Development: a) Do the students appear to have the correct data in their datasheets?	The student has attempted to input the data but has made significant errors or left out significant amounts of information..	The student has fully completed the datasheet but has made some errors or only focused on one soil type.	The student has correctly completed their datasheets for both soil types..	
b) Do the students connect their data to their hypotheses?	The student has attempted to connect data to the hypotheses but does not fully understand how to make this connection or the statement does not make sense in light of the data.	The student connects the data to their hypothesis, but it is very short or has some errors in light of the data, such as basing the assessment on only one pot.	The student has clearly and thoroughly drawn a connection between the hypothesis and the data.	
Biological understanding: Students gain an understanding of the role of water, sunlight, carbon dioxide to make glucose, water, and oxygen and where plants obtain these things.	Student only partially identifies the plant parts and resources (p. 8) and the items in the photosynthesis equation (p.9).	Student identifies most or all plant parts and resources (p. 8) and all components of the photosynthesis equation (p.9).	Student/team identifies all plant parts and resources (p.8) correctly and all components of the photosynthesis equation (p.9) and describe what photosynthesis is and why it's important (p.9).	
Ecological	Student describes	Student	Student describes	

Understanding: (Experiment logbook). Students are making connections to needs met by plants to how they emerged and how they are growing (p.10-11).	emergence and seedling growth/appearance occurring in one day and does not describe the differences they see between pots as a process tied to specific differences in the environment. The answers may be yes/no answers. The hypothesis to data connection does not include ecological reasoning.	describes 1 possible pattern of emergence or growth connected to 1 explanation to the cause of these differences in emergence. The hypothesis to data connection may have some basic ecological reasoning.	2 or more details in the pattern of emergence that are connected to how students may be able to tell which plants are getting more than what they need and which ones are not getting enough and specifically states the differences that have caused this. The data to hypothesis connection has thorough and correct ecological reasoning.	

KIDS into discovering science

Lesson 5: Evaluating Success

Overview & Guiding Questions

Students continue to take measurements and maintain plants and make preliminary comparisons across treatments. They discuss use of comparisons in science experiments to test hypotheses, and carry out comparisons of plants among student teams in class.

- How are comparisons used in ecological research?
- Why might comparisons among teams be useful in our class experiment?

Time Required

55 minutes

Preparatory Activities

None

Supplies

- Rulers
- Stakes
- Twist ties
- Scissors
- Colored toothpicks
- SmartBoard documents

Classroom Activities

Students continue to work in teams in where they make direct measurements of their growing plants, and carry out comparisons using their own plants and another team's plants. Students describe and assess plant height as a measurement for success. They describe how plants are continuing to grow, and place their personal data in the context of class data.

Objectives

Ecological Understanding

- Students will observe how soil type affects plant growth across multiple experimental units by comparing with another team.

Scientific Process

- Students will observe variation across the samples by comparing and contrasting with other teams.
- Students will be able to describe variation within the class data and why it is necessary to look at more than two pots.
- Students will continue to practice careful measurement and recording of data.

Sense of Place

- Students will continue to take measurements on an experiment based on local ecology.

LESSON PLAN OUTLINE

I. INTRODUCTION (10 MIN)
II. MEASURE PLANT HEIGHT (15 MIN)
   a. Thin plants as necessary
III. PROVIDE SUPPORT FOR TALL PLANTS (10 MIN) as necessary
IV. COMPARING MEASUREMENTS WITHOUT GRAPHS (20 MIN)

Adapt This!
This is a short lesson, mostly intended to provide additional time for experiment maintenance and additional data collection before moving on to more formal data assessment lessons (graphs and averages). It can be skipped if needed, or extra time can be used to discuss volunteer interests and pathways or the upcoming field trip.

LESSON PLAN

I. INTRODUCTION (10 MIN)

Review progress of experiment: we asked a question (what question?), made a hypothesis (what hypothesis?), set up the experiment, took emergence data, and started taking height data. We will continue taking height data for a few more weeks—then we will learn to use this data to answer our research question.

a. Remind the students of the comparisons they made between different soils and habitats in Lesson 1.
b. Emphasize the importance of making comparisons for science research (whatever comparisons of treatments you may do in your own research).
c. Tell the students that in today's lesson, they will have the chance to make comparisons with their own plants/soil treatments! (But first, we need to keep taking some data).
d. Emphasize that height is not the only thing we can compare—we can compare anything we can observe (color? mold?).

II. MEASURE PLANT HEIGHT (and thin as necessary) (15 MIN)

a. Measure height on each plant as you learned last week. (Review use of the datasheet). Note the "day" of the experiment. Record the data. *What does this entail?*
b. Volunteers: walk around as students are measuring and help them to thin plants as necessary (i.e. use scissors to cut all but the 3 focal plants that are marked with toothpicks)

c. **Experimental log:** the experimental log for Lesson 5 has questions for each pair (describing measurement methods, looking back at hypotheses). Discuss each question as a class.

III. PROVIDE SUPPORT FOR TALL PLANTS (10 MIN)

a. Briefly discuss why we might want to support the plants somehow. (Possible questions for students: *Has anyone noticed plants that seem unstable? What can we do about that? Beans often grow as vines – how do vines grow in nature? Has anyone ever seen plants crawling up a fence or a wall, or seen a gardener build a trellis?*)

b. To stake plants gently:

   i. Carefully place stakes in the soil about 1-2 cm from the base of the plant to avoid damaging plant roots.

   ii. Tie a twist tie to the stake about 7-8 inches above the soil.

   iii. Make a loop around the plant that is at least the size of your thumb. This will give the plant a little bit of room and will support it without damaging the stem. What would happen if ties were too tight on the stem (plants would wilt or break)? Why is that? (Stems transport water, nutrients and air throughout the plant).

   iv. Students whose pots have no plants can practice staking on pots of nearby groups that do have tall plants.

IV. COMPARING MEASUREMENTS (20 minutes)

a. *Scientists learn by making comparisons. We make comparisons between treatments (what are your treatments? What comparisons have you already made?), but we can also compare one team's results with another. Scientists who study similar questions are constantly discussing and comparing their results—these kinds of comparisons let us gather lots of information to answer our question!*

b. Each team will fill out the first column in **Part I** of the **Plant Growth Comparison Datasheet,** making comparisons between their own plants/soil types.

c. Teams should exchange pots with another team sitting nearby, and fill out the rest of Part I in the datasheet. If teams need guidance, the class can do one step at a time together. *Remind the students: Remember that these new pots have been carefully tended, observed and measured by the other team. Treat the other team's plants very, very gently!*

d. **Class discussion***: Did you find it easy or difficult to decide on answers when you were asked to compare the heights of plants between groups and between soil types (questions 3a and 3b)?* Groups can volunteer to answer each question. Students should discuss why it was sometimes difficult to compare groups of numbers to each other. (**Important point:** It is especially hard to compare groups of numbers when there is a lot of variation within each group. In this case, variation in plant height within a pot may mean that there is overlap in the height range between groups you are trying to compare. It can also be hard to compare more than two groups at a time, or to compare groups in which the measurements are very similar to each other.)

e. **Optional discussion points**: *Could some of the variation we observe be due to measurement error? It is hard to measure plants gently and accurately because of their irregular shapes. Is there some way we could figure out how consistently we can measure plants?* (One approach: use the last column of the height data table on the Plant growth comparison datasheet to compare measurements made on the SAME plants by two different groups.)

f. Carefully return all pots to their "home" teams.

g. **Make sure that datasheets are filled out!** If students have only written data for one plant from their team on the chart, they should get the data for the other plant from their partner(s).

Adapt This!

The second part of the lesson focuses on comparison. The main idea is to get students thinking about comparison between different treatments at different sample sizes--between their own plants, between their plants and another pair, and at the whole class level. This idea can be explored in a variety of ways and for different experiments. If you have time, have students move around the room to see all of the variation in the pots.

Lesson 6: Seeds and Seedlings in Action

Overview & Guiding Questions

Seedling emergence gives students the opportunity to learn how to monitor growth, interpret collected data in histograms, learn about seedling characteristics, and enhance their scientific observation skills.

- Did the emergence period last longer in one soil type than the other?
- Are teams finding different results?
- What is a seed and what are the parts of the seed?
- How do seeds from different species compare?

Time Required

90 minutes

Supplies

- Dry seeds of beans and a variety of other species, with a set of beans for each group and enough other samples for groups to see several types
- Soaked bean seeds (1 set per group)
- Sprouted bean seeds (1 set per group)
- Jeweler's loupes
- Rulers
- Toothpicks
- SmartBoard file

Preparatory Activities

- Soak bean seeds (and other species if time allows) 5-7 days in advance of the lesson as necessary to have soft seeds and some sprouts of at least the beans.
- Organize seed collections for each team.

Classroom Activities

Students will discuss their data and look closely at the progress of their seedlings in each soil type with the use of bar charts. Students will dissect lupine and bean seeds to become familiar with the similarity and differences on how they germinate.

Objectives

Ecological Understanding

- Students will be able to identify the basic parts of a seed.
- Students will be able to describe how differences in seed size and other features contribute to seed dispersal and germination success under different conditions.

Scientific Process

- Students continue to practice observation and comparison.
- Students create a composite bar chart and learn one way to summarize and visualize data.

Sense of Place

- Students examine seeds from local plants.

LESSON PLAN OUTLINE

I. INTRODUCTION, OBSERVING THE DATA COLLECTED (15 MINS)
II. INTERPRETING GRAPHS (25 MIN)
III. SEEDS AND SEEDLING ACTIVITY (40 MIN)
IV. CHECKING OUR FINDINGS (10 MIN)

LESSON PLAN

I. <u>INTRODUCTION (15 MINS)</u>

a. *How have your pots changed over the past week, what have you observed?*
    i. They have been thinned, students have been measuring height.
    ii. *Are seedlings still emerging?*
b. *We asked you to make 2-3 sentence reports on your emergence charts a week ago today. What observations were you making a week ago* (have 2 students read reports aloud)?
c. *What else would you add to your report now? Have you observed any emergence since you thinned?*
d. *You took several emergence records that you added to your emergence data chart. Was it difficult to explain all of these different measurements in a short statement? Or simple?*
e. *Science reporting and writing has to be very fast and to the point. We often have a lot of different bits of information that we are trying to summarize and understand. That's why charts are so nice they tell you a lot just by looking at a picture. The kind of chart that you made for emergence data is called a bar chart. It is a way of counting things in different categories, in this case emergent seedlings on different dates.*
f. Teams make reports to the class. Volunteers make notes on the board, summarizing all of the data.

II. <u>INTERPRETING GRAPHS-MAKING A COMPOSITE GRAPH (25 MIN)</u>

a. Compare differences between soil types for each species. *Did the same number of seeds emerge on each of the soils? Can we make a generalization? Are teams finding different results?*
b. *One way that we can think about all of the results from the different teams together is to make composite bar charts including ALL of the plants in the class. We can do this by adding the results from all teams together. (If you made emergence histograms in lesson 3, use a histogram instead).*
c. *First let's do all of the SERPENTINE pots.* Draw a bar chart on the board or overhead for the whole class by adding all of the plants from each team on each of the 4 emergence sampling days. Show the math!

i. Emergence 1=team1+team2 etc=50
ii. Then plot emergence 1
iii. Then do emergence 2, 3, and 4 in the same way.
iv. Then do the NONSERPENTINE pots.
v. Do this on the Smartboard using the composite chart.

d. *Did the emergence period last longer in one soil type than the other?* Discuss what that might mean.

III. <u>SEEDS AND SEEDLINGS ACTIVITY (40 MIN)</u>

a. **Introduction (5 min)**: *Since we are thinking about the emergence period and what was going on with the seeds and seedlings as they started to grow, we're going to step back a bit today to the start of our experiment and take a really good close look at the seeds that we planted.*
   i. *What is a seed exactly?*

b. **Dry seeds (10 min)-Use bean seeds and whatever seeds you have available and prepped. You can use local seeds, vegetable seeds, or both. You can choose a small number of seed types in replicate that each group can see at the same time, or bring a wide variety of seed types (as many as 15-20) and rotate them around the room during the observation period so that each student gets to see several kinds. Try to include seeds that vary in size, shape, and dispersal mechanism (e.g., fluffy wind dispersed seeds, prickly animal dispersed seeds, seeds with large fleshy fruits).**
   i. Hand out dry seed collections, labeled.
   ii. <u>Directions:</u> examine the dry seeds and discuss as a team how they are different. Note differences in scale, shape, color between species on the experimental log for Lesson 6. Students should draw the bean seeds as well as at least two other species.
   iii. *<u>Question:</u> are seeds from each species all the same?*

c. **Soaked seeds (15 min):** *Now we will take a look at seeds of beans that have been soaked in water for a couple of days, as if they had been planted in damp soil.*
   i. Hand out soaked seeds (beans) and toothpicks.

<u>Adapt This!</u>
- Use local seed species, or a combination of local and non-local species for comparison.
- If needed, simplify by looking closely at bean seeds only (the seeds in the experiment).
- The seedling activity can stand on its own, apart from the experiment.

ii. *Examine these seeds. Use your fingernails and your team's tools (wooden toothpicks) to explore them. Can you peel off the outside of the seeds without damaging the inside? Is this easier for one species than another?*
iii. *Use your thumbnail to gently pick the seed apart so that you can see the different parts of the seed. Draw the different parts that you see. Raise your hand when you think you have identified the parts of the bean. We'll stop for discussion when most teams are ready, in about 10 min.*
iv. <u>*Discussion:*</u> *What did you see when you picked the germinating seed apart?* Allow students to describe what they saw, as they describe one team member draws the parts of the germinating seedling on the board.
v. *The parts of the seed are the seed coat, root, leaves, and food storage.* Discuss each of these with the class and have them identify them on the board and the drawings on your team's seeds handout.
vi. Spend another 10 minutes dissecting the other species. Make sure each student has a chance to do a dissection.
vii. Draw your dissections on your seeds hand out.
viii. Discuss any differences found between the different species in your team.

d. **Sprouts (10 min):** hand out bean sprouts to each pair.
i. As a team, find the parts of the seed on the sprout. *Are they all still there? Draw them on your handout for comparison.*
ii. Discuss any differences found between the different species and (if time allows) write a 2-3 sentence statement about the differences between the seeds and sprouts of the two species on the back of the seeds handout.
iii. CLEAN UP

1. **<u>CHECKING OUR FINDINGS AND NEXT WEEK (10 MIN)</u>**
   a. *Let's go back to our <u>hypothesis on the experimental log that your team completed for Lesson 2</u>. What are some of the hypotheses that you posed?*
   b. D*o we have any information that we can use to address these hypotheses? What other kinds of information should we still collect?*
   c. Continue this as discussion if time allows or as a journal entry.
   d. *For next week, we will continue taking height measurements. Think about how we can use these to address our hypotheses. What does*

height tell you that emergence does not? Do you wish you still had all the plants to measure? Or is three enough to draw a conclusion from?

Assessment for Lesson 6

Student Name(s): __________________ Date: __________________

Level of Understanding ⇨ **Indicator** ⇩	**Engaged** 1 points	**Emerging** 3 points	**Proficient** 6 points	**Total Points**
Scientific Skill Development Observation of key characteristics in seed differences (Lesson 6: seeds in experimental log book)	Students use 1 word examples for categories in the seeds table and no picture	Students use multiple descriptive adjectives and/or a picture	Students use multiple adjectives and a picture or use some statement of comparing or contrasting	
Ecological/Biological Understanding Understanding of key seed characteristics in the process of germination	Students give limited or one word response	Student give one or more descriptive responses and/or a descriptive picture	Student describe both soaked seed and sprout using descriptive words, size information, and/or comparisons	

Lesson 7: Visualizing Plant Growth With Graphs

Overview & Guiding Questions

Students learn how to represent measurements taken over time on graphs to visualize plant growth on two soil types. Key to any experiment is the value of comparison between groups for testing hypotheses, and comparing observations.

- How do graphs help us to visualize and understand scientific evidence?
- How do you interpret the data in different types of graphs?
- How do you create a graph to visualize and understand your data?

Time Required

75 minutes

Preparatory Activities

None

Supplies

- Rulers
- Extra graph paper
- Colored pencils (optional)
- SmartBoard documents

Classroom Activities

Students will take their last observations and think about how what evidence they can glean to address their hypothesis from their plants and data charts. Then, students will learn about the elements of an x-y graphs and practice interpreting them, leading into creating their own graphs of their own data that represent each height over time.

Objectives

Ecological Understanding

- Students will be able to describe how variation in plant growth rates varies under different treatments.

Scientific Process

- Students will be able to identify the major parts of an X-Y graph and interpret a variety of real world graphs.
- Students will create X-Y graphs of their experiment for each soil type.
- Students will begin to use their data to assess whether the evidence supports their hypothesis.

Sense of Place

- Students will begin to understand the implications of their experiment for local ecology.

LESSON PLAN OUTLINE

I. MAKING FINAL HEIGHT MEASUREMENTS (15 MIN)
II. LEARNING ABOUT XY GRAPHS (30 MIN)
III. CREATING XY GRAPHS (30 MIN)

LESSON PLAN

I. <u>FINAL MEASUREMENTS (15 minutes)</u>

a. *Today's first experimental task is to measure the height of the three bean plants in each of your two pots for the last time. As you measure each toothpick-marked plant, write down today's height (in centimeters) for each plant on your Plant Growth Datasheet under the correct soil type. Since it is the last day of data collection, make sure that your datasheet is completely filled out. Check that Day of Experiment is complete (write these numbers on the board next to the dates so that everyone can be sure it is correct).*

b. *Congratulations—you have all completed the data collection part of our experiment! That was a lot of work, so give yourself a pat on the back. However, we aren't done yet. It's time to visualize and analyze our data so that we can better understand our results and make it easy to share them with other people.*

c. *What was our research question? What was our hypothesis? By looking at your datasheets, can you figure out whether the results of our experiment support our hypothesis? Why or why not?*

d. *A table full of numbers isn't the easiest way to understand our results. A graph is a great tool to summarize your data to quickly and clearly understand overall trends.*

> **<u>Adapt This!</u>**
> This lesson can be taught using nearly any type of experiment with quantitative data that changes over time. The data can come from a long-term experiment as in our curriculum, or it can be pulled in from an existing data source for a standalone lesson on graphing.

II. <u>GRAPHS CAN HELP YOU TO SEE PATTERNS AND DIFFERENCES (30 minutes)</u>

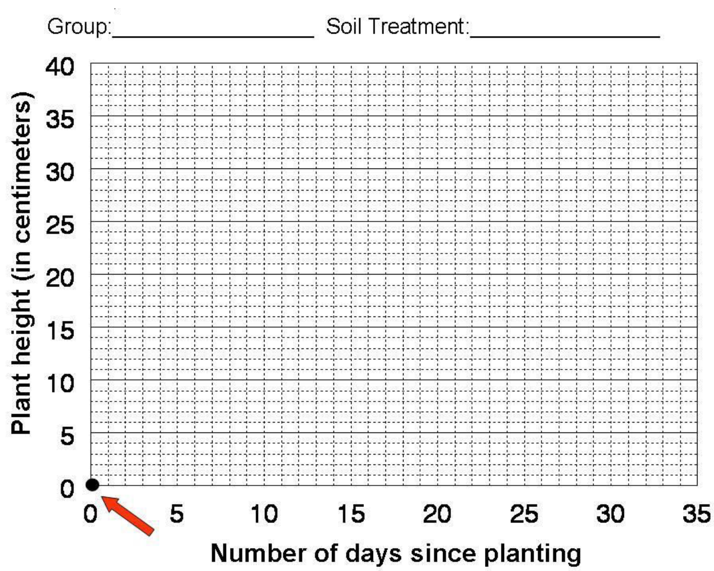
a. *The height measurements that you have been taking can be summarized into graphs that make it easier to see patterns and differences. We'll take a look at a few different kinds of graphs and see how to interpret them.*

b. Project the sample graphs, one at a time: start with a couple of silly graphs (e.g. Cuteness vs. Number of Legs on Animals, Fun vs. Effort for Pets), then move on to a real scientific graph (e.g. CO2 at Mauna Loa). Practice interpreting the graph by asking questions:

i. *What is the title? What does this graph show?*
ii. *The horizontal axis is called the x-axis, and the vertical axis is the y-axis (label them on the Smartboard). What is being measured on each axis in these graphs?*
iii. Ask specific questions that the students need to interpret the graph to answer (e.g. If an animal has 6 legs, how cute is it? How much effort and fun is a pet dragon, based on the graph? How much CO2 was there in 2005?). Have students explain how they figured out the answer. Finish with the kids' growth chart as an example of height measured over time.

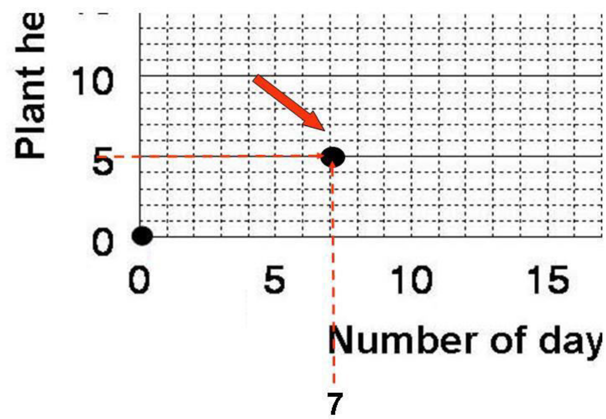
Adapt This!
The sample graphs can be modified to include locally relevant or timely graphs, whether silly (age appropriate pop-culture) or serious (current events).

c. Summarize how to interpret and plot locations on an XY graph**--**Project a blank version of the Bean plant height growth template (Growth charts blank.pdf) on the Smart Board. NOTE: Remind students not to plot the example points on the graph paper they need to plot their own data!
i. *This is an "XY graph" that we can use to see patterns in how plants grow over time. Every location within this graph area has an address indicating its location along each of the two perpendicular lines or axes.*
ii. *The horizontal line is called the X-axis, and it shows us time as our experiment has progressed. It starts at day 0. The first height measurements we took were on Day 7, and today is day __ of our experiment*. (Point to these numbers on the X-axis as they are presented).
iii. *The vertical line shows us how tall above the ground plants were at each date when we measured them. <u>Question:</u> How "tall" were the plants when we planted the seeds?* <u>Answer:</u> We would have measured them as having no height on that day, and so we can say that all plants had a height of 0 on day 0 of the experiment. So, we draw a filled-in circle at the (x, y) point (0,0) that represents all three seeds planted on that day. (The point (0,0) is called the "origin" of an XY graph.) At this time, all of our graphs should look like this:



i. *Any location on this graph can be located by knowing its x value and its y value (we describe the address in the following format: (x,y). The first number of the address is the X value and the second number is the Y value.*
   1. <u>*Question:*</u> *Where is point (10,40) on the graph?* (Student volunteers can come forward to locate that point)
   2. <u>*Question:*</u> *Where is point (30,35) on the graph?*
   3. <u>*Question:*</u> *What does the point (30,35) really represent?* <u>Answer:</u> We have to read the descriptions of each axis to know what points represent. On this particular graph, the point (30,35) represents a plant measured on day 30 of the experiment that was 35 centimeters tall.

ii. Project a blank graph with a datasheet next to it, and fill in some example data (can make it up or borrow from students). *Any height measurement that we've made in our experiment can be mapped to a point (x,y) by knowing the day on which it was measured (x). Let us say that on day 7 (that means that x=7), you measured the height of three plants in your non-serpentine pot, and those heights were: 5 cm, 6.9 cm, and 2.5 cm (or the sample numbers you have chosen). These are the y-values corresponding to the three measurements. We can plot the first new height measurement (5 cm) by finding day 7 on the X axis, and then moving upward until we are directly across from the value 5 on the Y axis. We can mark the location of that observation on the graph at point (7,5), as shown below.*



iii. *Now, following the same procedure (starting at day 7 and moving upward), we mark the two points that correspond to the next two plant measurements: point (7, 6.9) and point (7, 2.5). We can use different symbols or colors for each plant. If using shapes, write the shape we will use into the datasheet under the color name so that we don't forget which is which (do this on the example datasheet on the Smartboard). Circle is pink, triangle for blue, square for yellow/green.*

III. MAKE XY GRAPHS FOR EXPERIMENTAL BEAN PLANTS (30 MINUTES).

a. At this time, each group should plot their own bean plants' height over time, by plotting data from their plant growth datasheet onto two blank graphs (Growth charts blank.doc). It's usually easiest for students to take the datasheet out of the binder, so that they can look at the datasheet and graph side by side. Also, this part works best when teachers work directly with teams or individual students. Explain the process, but if they don't understand completely, it is usually better to move on to going around and helping at their desks one-on-one.

   i. To distinguish the two soil treatments, one graph should be labeled "Serpentine"; the other should be labeled "Non-serpentine."
   ii. For each Experiment Day located along the X-axis, students should plot three plant height measurements (one toothpick color at a time) by comparing the heights they measured to values on the Y-axis. Alternatively, they can do each day for one

toothpick color, then go back to Day 0 for the next, etc. First, start with the plant marked by the pink toothpick. Plot the Pink plant's "height" when it was planted on Day 0. Next, plot the Pink plant's height on Day 8 (or whatever the next measurement day is), and then continue plotting for the other days on which this plant was measured. Next, connect the points you've drawn in pencil with a ruler. Once your graph is complete for the Pink plant, trace over your points and connect them with lines in pink. This graph is a picture of how this individual plant has grown over time!

iii. Repeat this procedure for the Blue plant, and then for the Yellow plant. Always remember that data points and connecting lines should be sketched in pencil until the other team member confirms that each point is plotted correctly. THEN, add the color! (Or, if you don't have colors, use shapes.)

b. **Using graphs for comparison--** Now that you've all made your graphs, each team should place the graphs for your serpentine and non-serpentine pots side by side, so that the X-axes are lined up as closely as possible.

i. *Question: Can you see how the graphs give you a visual picture of how plants are growing over time on the two soil types? Have the plants stopped growing, or are they still growing fast?* (Likely answer: Bean plants still seem to be growing fast, as their heights are not showing any signs of "leveling off" on the graphs.)

ii. *Question: From the graphs, does it look like your plants are growing at the same speed over time, or are they growing faster or more slowly over time?* (This is an advanced topic, but let the students try to understand how they could use the graphs to figure it out.) Answer: On an XY graph, a steeper upward curve or slope means faster growth.

Iii. *Question: Do the graphs help you understand whether your data supports your hypothesis? Why or why not? Is it better than the datasheet? Why or why not? How does having one line for each plant helpful? How is it unhelpful?* Since plant heights within a pot are different, we need to learn how to calculate "average" plant height to better understand whether our hypothesis is supported. That is the goal for Lesson 8.

PREPARATION FOR LESSON 8:

Davis instructors should photograph the Plant Growth data sheets for calculating class averages only if there is time.

Assessment for Lesson 7

Team/Student Name(s):__________ Date: _______________

Level of Understanding ⇨ **Indicator** ⇩	**Engaged** 1 points	**Emerging** 2 points	**Proficient** 3 points	**Total Points**
Scientific Recording (3b & L7.doc Plant Height Graph) Teams of students accurately record and represent their data!	Team makes numeric observations of plant height and 25% are reflected accurately in graphs and graphs are correctly labeled.	Teams makes numeric observations of plant height and 60% are reflected accurately in their graphs and graphs are correctly labeled.	Teams numeric observations of plant height and 80% or more are accurately reflected in their graphs. Graphs are correctly labeled.	
Scientific Skill Development: (3a) Student displays understanding of variation.	Team only states that new bean plants are either taller or shorter and makes no comparison with their own.	Team states that new bean plants observed vary, some are taller some are shorter and makes no comparison with their own.	Team describes that new bean Plants, some are shorter others are taller making it difficult to compare with their own bean plant.	
Ecological Understanding (3b & 3c)	Team makes 1 clear observation and connection between bean plant growth and soil type.	Team makes 2 clear observations and connection between bean plant growth differences to soil types.	Team makes 2 clear observations and connection between bean plant growth differences and similarities, to soil types and makes references to the influences of time.	

KIDS
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Lesson 8: Which Group Is Taller, On Average?

Overview & Guiding Questions

Students discuss how to summarize data and why summarizing and visualizing data can help answer a research question. Students learn how to calculate averages and calculate and graph average plant heights for class data, using this information to assess their hypotheses.

- How does variation in our data affect our ability to answer our question?
- What are some different ways we can summarize our data to make it easier to answer our research question?
- How do you calculate an average, and why are averages useful?

Time Required

80 minutes

Preparatory Activities

Take photos of datasheets following final measurements for all groups prior to Lesson 8 and calculate class averages.

Supplies

- Meter sticks or measuring tapes
- Calculator
- Pre-calculated class averages

Classroom Activities

Students learn about averages first through an interactive activity. Then, they apply what they learned to calculate averages for their data themselves and make graphs of class averages. Finally, students discuss why averages are useful and use their new graphs and calculations to their original research question.

Objectives

Ecological Understanding

- Students will be able to continue to describe how plants grow differently under different soil treatments.

Scientific Process

- Students will be able to describe why summarizing data using ranges and averages is useful.
- Students will be able to calculate average values for experimental data.
- Students will graph calculated averages on X-Y graphs.
- Students will assess whether the data support their hypotheses.

Sense of Place

- Students will begin to understand the implications of their experiment for local ecology.

Adapt This!

This lesson can be taught using nearly any type of experiment with quantitative, variable data. The data can come from a long-term experiment as in our curriculum, or it could be a one-time activity, like measuring student heights in the group discovery exercise described in Part II.

LESSON PLAN OUTLINE

I. INTRODUCTION AND DISCUSSION (15 MIN)
II. GROUP DISCOVERY EXERCISE (20 MIN)
III. CALCULATING AN AVERAGE PLANT HEIGHT (20 MIN)
IV. PLOTTING AVERAGE PLANT HEIGHT DATA OVER TIME (15 MIN)
V. WRAP-UP DISCUSSION (10 MIN)

LESSON PLAN

I. **<u>INTRODUCTION AND DISCUSSION (15 min)</u>**

a. *You have all been busy measuring your experimental bean plants and plotting your height measurements over time.* Question: *Why are you doing this?* (Answer: To test your hypothesis that plants will grow differently to serpentine and loam soil.)

b. *So far, do you think that bean plants grow better on serpentine (*count hands*), on loam* (count hands*), or does it seem like the plants don't care or you don't know (*count hands*)?*

c. *Chances are that none of you feel completely certain about your answer so far. What are some of the reasons?* (**Write on board:** e.g. different groups' plants didn't grow the same, plant size varied within pots/treatments, plants are hard to measure well, the treatments don't seem to make a big difference, etc…)

d. *Let's find out just how variable the heights of our plants were within each treatment.*

  i. *Everyone, what was the last day on which you measured the height of your bean plants?* (Look at the last measurement day on the Bean plant growth chart.)

  ii. Starting with one team, ask for their tallest and shortest measurements on each soil type. List these data points on the board in two columns labeled "serpentine" and "loam." Ask if any group has a shorter or taller measurement for either soil type. The goal is to discover the shortest and tallest measurements in the entire class for each soil type.

iii. *What is the shortest plant we've seen growing on loam? What is the tallest plant on loam? What is the shortest plant on serpentine? The tallest plant?* (These measurements are circled on the board.)

e. **Experimental Log Question 1:** How big was the difference between the tallest and the shortest plant grown on each soil type (what is the **range** of values)? Based on circled measurements on the board, teams will fill in the table on their **Experimental Log** to answer this question. (Question 2 will be answered after the Group Discovery Exercise, during part III.)

f. So now that we have all of these numbers up on the board, it might be hard to tell whether one soil led to taller plants than the other since there is so much variation. *Can you think of any way we might be able to summarize all of this data to see if serpentine or loam soil led to larger plants?* If this not mentioned, point out that we can take the average to find out the answer (it is unlikely that they will have heard of this). *One way we summarize the group is to calculate an average. And you are going to figure out how to do it!*

g. *An average is a number that summarizes a lot of different data points. Averages help us make predictions—for example, if we knew the average height of a 5th grader, we'd be able to guess pretty well how tall a kid in this class is likely to be. That number might help us if we want to pick out desks and chairs for the classroom, or help us understand how much kids grow between 5th grade and 9th grade.*

h. *This is a hard concept to understand, so we're going to do an activity to help you understand how we calculate and use averages.*

II. **GROUP DISCOVERY EXERCISE—CALCULATING AVERAGE HEIGHT WITHIN GROUPS (20 min)**

a. *When a scientist tests hypotheses, she usually need to compare the characteristics of different groups—those groups may have been exposed to different experimental treatments (like your plants), or they may have had different histories that you did not control.*

Adapt This!
The group discovery exercise can stand on its own as an activity to learn about averages, though it works best when students are able to see how averages are used in the context of an experiment.

b. *Let's imagine that you are all a big team of scientists, and you'd like to know whether people who prefer chocolate ice cream or strawberry ice cream are taller. Remember when we made a hypothesis about the bean plants and their heights. Do you have a hypothesis (a prediction) for whether people who prefer strawberry or chocolate ice cream will be taller? Why? Let's say that we hypothesize that people who prefer strawberry are taller because strawberry ice cream is more nutritious. To figure this out, we'd have to do an experiment, right? That would require a lot of ice cream, and time, and all sorts of permission from you and your parents, and a lot of effort (Scientists DO this with people, for example, when they are testing new medicines!).*

c. *What we can do, for now, is to compare the heights of the students in this class who prefer chocolate or strawberry and see if we have a trend. We're going to need some volunteer test subjects here for our study!* Have students who prefer chocolate raise their hands, randomly select 7 of them to go to one of side the room, then repeat with strawberry but use 6 or 8 students.

d. *This isn't exactly a perfect study, but for now, we'll figure out how we can tell which group is taller, on average.*

e. *For starters, can we just look at the groups and tell which group is taller?* Discussion.

f. *Can we just measure the tallest student in each group? Or the shortest? And then decide based on that?*

g. *Somehow, we need to "see through" the variability within each group to figure out which one is taller, on average. To do that, we need to measure each person in each group and then figure out how to summarize all of those heights.* The volunteer instructors and teacher help to measure each student; write down the heights as two columns of numbers on the board.

h. *Now what do we do with all of these numbers to compare them? Maybe we need to add up all of those heights within each group… if there are lots of tall students in the group that will be a bigger number.* Add up the heights for each group, and write the total on the board.

i. *But, can we really compare these two totals?* Lead the students to realize that the comparison isn't fair, because there are more students in one group than in the other.

j. *What can we do to make the comparison between the two groups "fair"?* Lead the students to the idea that you have to divide the height total by the number of students in the group. This is the average height for a group!

k. Volunteer instructors displays the method for calculating the arithmetic mean of a group on the Smartboard, leaving it up for reference by the students.

   i. Count the number of individuals in the group

   ii. Measure each individual

   iii. Add up the measurements for the whole group

   iv. Divide the total by the number of individuals in that group

l. *So we've found that the group that likes _____ ice cream better is taller. But what if one short person who liked _____ ice cream transferred into this class – would that be enough to change which group is taller on average?*

m. If there is time, expand on the discussion by adding a teacher or volunteer instructor (significantly taller than the students) or ask what would happen if we added in a pet or younger sibling. Lead students to the conclusion that an average is brought up or down by bigger or smaller numbers and that extreme values can skew the result and make prediction more difficult.

n. *What do you think – if we knew the heights of everyone in the world who prefers either strawberry or chocolate, do you think we'd still get the same result? Why or why not? In other words, do you think there's a real reason that people who prefer __ ice cream are taller, or do you think it's just a coincidence that people who prefer __ in this classroom happen to be a little taller?*

III. **<u>CALCULATING AVERAGE PLANT HEIGHT (20 MIN)</u>**

a. *Now let's do the same thing for your bean plants! This is how we can determine which treatment is really doing better overall than the other in terms of heights.*

b. The first step is for each team to calculate the average height of its three serpentine bean plants and its three loam bean plants.

   i. The volunteer instructors work out one example on the board, using three hypothetical heights.

ii. Each team uses its most recent plant growth data sheet and the Lesson 8 Experimental Log to calculate the average heights of the plants growing in their serpentine and loam pots. Use the most recent heights that you measured, and fill in the table on the experimental log (**Experimental Log Question 2**).

c. *Let's read out the averages that each team calculated!*

i. Write these on the board (next to the individual plant measurements).

d. Discussion: *OK, now let's say we want to know whether or not serpentine or loam plants are taller for the entire class's data? How could we calculate that?*

i. We calculate the average bean plant heights for the whole class by taking the mean of all team averages.

ii. The volunteer instructors demonstrate this, with help from student teams, for the most recent height data in the serpentine and loam soil treatments. These new whole-class means for each measurement day and soil type should be written on the board and circled.

iii. Is the average plant height for the whole class (say, on loam soil) higher or lower than the average in your team's pot? (Teams call out, in turn, demonstrating that some will be higher and some will be lower.)

e. *Now let's fill in the table of data that summarizes all of your whole classroom's bean height growth data.* Below, each team should fill out the table of summary data on their Experimental Log (question 3). Remember that THIS table is for all the class's height measurements, not just the data for individual teams.

i. **Experimental Log, Question 3:** *We will fill in the table with our whole-class height averages for two measurement days.* The first is day ___ (the volunteer instructors will have chosen a day and calculated the class average earlier). We could go through the same process to calculate the class averages for that measurement date. That would take a little too long today, so we calculated the average for you.

ii. The second blank row in the table is for the most recent measurement day. *We just calculated the average heights for our serpentine and loam treatments on our last measurement day, and they are written on the* *board. What was that measurement day?* Fill those averages for that day on the table.

IV. PLOTTING AVERAGE PLANT HEIGHT OVER TIME (15 mins)

a. *Wow, we have been doing a lot of math! It's time to remember WHY we need to summarize our plant growth data this way!* (To help us see patterns that will test our hypothesis.)

b. *In your binders, take a look at the graphs you have made so far, plotting the growth of your team's bean plants in each soil type. Because individual plants are growing differently, imagine how confusing it would be to try to look at all of those graphs for all of the teams at once!*

c. *Now, instead of plotting individual plant height measurements, we will plot average plant height over time for BOTH of our soil treatments on the same graph. This will help us to consider the question that motivated our experiment—do plants respond differently to these two soil types?*

d. On the SmartBoard, show the calculated class mean values and have students complete the table in **Question 3**.

e. Next, on the SmartBoard, display a blank growth chart. Using the means written into the table for **Question 3,** the students are shown how to plot the height means over time, giving two different symbols for the serpentine treatment and the loam treatment.

f. With help from volunteer instructors, each team now plots the class average data for both treatments on a single graph (Experiment log **Question 4**). While students are filling in their graphs (IN PENCIL!), the Smartboard graph is also completed, except for the lines connecting the means within each treatment.

g. Now, let's use our new summary XY graph!

   i. *Notice that it is easier to see differences between treatments if we connect the plotted means within each treatment by lines.* (Demonstrate this on the Smartboard.)

   ii. Those lines allow us to see quite easily how fast plants are growing over time. A steeper line means faster growth! Based on this graph, do you think that bean plants are growing faster in one soil? If so, which one?

V. DISCUSSION AND WRAP-UP (15 mins)

a. *Which plants grew taller on average – the ones we planted in serpentine soil or loam soil?*

b. *What are some possible reasons that the plants on (serpentine/loam) grew taller?*

c. *Today we learned a strategy for summarizing the data for lots of individuals: calculating an **average**. We've posted on the SmartBoard a graph of lots of individual plant heights. Which plants grew taller: the ones on serpentine or loam?* (Vote by raising hands).

d. *Okay, here's a graph showing just the average plant heights. Now which plants do you think are taller? (Vote by raising hands).*

e. *Which graph was easier to understand: the first one, with all the individual plants, or the second one, that just showed the averages? What information does the first graph give you that the second does not? Is one better than the other? Why or why not?*

f. *Revisit your hypothesis—do our results support your hypothesis? Why or why not?*

g. Finally, review how to calculate an average and discuss why this is a useful tool. *How did averages help us answer our research question?*

Assessment for Lesson 8

Team/Student Name(s):___________ Date: _________________

Level of Understanding **Indicator**	**Engaged** 1 points	**Emerging** 2 points	**Proficient** 3 points	**Total Points**
Scientific Recording & Skill Development A (1 & 2) Teams of students record class data and calculate ranges and averages.	Team writes down individual and class data and attempts to calculate range and/or averages, with major errors in calculation methods or missing information.	Team writes down data and calculates range and averages, with some calculation errors.	Teams correctly record and calculate both ranges and averages with only minor errors, if any.	
Scientific Skill Development B: (3a) Students graph class averages for two soil types on one graph.	Team graphs the class information, but with errors, such as mixing up axes or only one soil type.	Team graphs the class information, but with minor errors or without adequate labels.	Team correctly and completely graphs the class data, with labels complete where necessary.	
Ecological Understanding (3b & 3c)	Team makes 1 clear observation and connection between bean plant growth	Team makes 2 clear observations and connection between bean plant growth	Team makes 2 clear observations and connection between bean plant growth differences and similarities, to soil types and makes	

	and soil type.	differences to soil types.	references to the influences of time.	

Lesson 9: Jeopardy!

Overview & Guiding Questions

Students review what they have learned from previous lessons and apply their knowledge in new ways with a game modeled on Jeopardy!.

- What…..? (what new terms and concepts did we learn about?)
- Why….? (why did we do our experiment in the way we did?)
- How…? (how would you use what you learned in a new context?)
- Who…? (who are the scientist volunteers that you met and what did you learn about them?)

Time Required

60-90 minutes

Preparatory Activities

Edit question pool to fit topics covered and current volunteer trivia.

Supplies

- Question pool
- Prizes (optional)
- SmartBoard file with Jeopardy! board and photos/images that go with questions.

Classroom Activities

The lesson begins with a student-led review of the whole curriculum, including the scientific process and ecological principles introduced, with an emphasis on major takeways and difficult terms and topics. Then students divide into teams and play Jeopardy!

Objectives

Ecological Understanding

- Students will be able to describe major ecological concepts from the program, including habitats, soil, plant growth, and photosynthesis.

Scientific Process

- Students will be able to describe elements of the scientific method and describe how the different parts of their experiment fit that model.
- Students will be able to identify key elements of basic experimental design and come up with ideas for new experiments based on what they have learned.
- Students will be able to explain what a hypothesis is and how data can be used to assess whether a hypothesis is supported.
- Students will be able to read X-Y graphs and bar charts and be able to plot data on these graph types.
- Students will be able to calculate averages for simple datasets.

Sense of Place

- Students will review their own place-based experiments.
- Students will answer questions about local habitats and environmental processes.

LESSON PLAN OUTLINE

I. INTRODUCTION (10-15 MIN)
II. JEOPARDY (45-60 MIN)
III. WRAP-UP & FIELD TRIP REMINDERS (10 MIN)
IV. EXPERIMENT BREAK-DOWN (10 MIN)

LESSON PLAN

I. <u>INTRODUCTION (10-15 min)</u>

Objective: Conduct a class discussion that reviews/summarizes the experiment. Emphasize important or tricky concepts that will help students succeed in Jeopardy (e.g. graphing, averages, treatment comparisons, hypotheses).

a. *What did we do last week?*
b. *Does anyone remember where we are going for our field trip in a few weeks?* Discuss field trip site (if applicable), remind students that it is local and that there are a lot of different habitats (creeks, grasslands, serpentine plant communities, etc.).
c. *Before we go on the field trip, now that we've finished collecting our data and analyzing it, we're going to work on the final step in our experiment, which is reporting the results.* Have students contribute to a brainstorm on the Smartboard of the following: Research Question, Hypothesis, Methods, Analysis, Results, and Discussion.
d. *Why might someone care about our experiment? Why is it interesting to look at what affects plant growth? Who might be interested?* (ask leading question depending on their responses – "Like what?". Possible directions: food, farming, animals)
e. *Why is summarizing our experiment such a critical last step for our experiment?* Discuss the importance of communicating results. Possible questions/topics: scientific conferences and/or journals; other scientists can verify your results; you or others can repeat your experiment; your results can be applied to world problems by other people; your results can be combined with other peoples' findings to answer complicated questions.

II. <u>JEOPARDY (45-60 min)</u>

Today we are going to play a game to review some of what you learned during your plant growth experiments.

a. Load blank Jeopardy board onto Smartboard. See questions at the end of this lesson.
b. Explain the rules: *Has anyone heard of or played Jeopardy? Today, here's how our version of Jeopardy works: We have 6 categories (which are*... read them*), and each category has questions worth 100-400 points. 100 point questions are the easiest, 400 point question are the hardest.*
c. Divide the class into groups (4-6 groups total)
d. Continue explaining the rules: *When it's your groups turn, you will pick a question (say category and point value), and if you answer it correctly, you get those points. All the other groups should also work on the question, because if the first group gets it wrong, other groups will have a chance to answer. Partial points are possible. Any questions?*
e. Have groups come up with team names, write names on the board.
f. *Remember, points may be deducted for disrupting or distracting other teams. (Example: counting down remaining time). And remember to LISTEN when other teams are giving their answers, because if they get it wrong, you don't want to repeat the same wrong answer.*
g. Play! Pick a respectfully quiet group to go first. After they pick a question and you read it, immediately designate time for them to discuss amongst themselves *("Okay, you have... 20 seconds to decide on an answer. Go!").* If they are tackling a confusing question and they misinterpret it, it's okay to guide them a little.
h. If a group answers a question incorrectly, here's one way to run the show: Have all other groups put their hands down on their desks, then on the count of 3 they can raise them. The first group to raise their hands gets the chance to answer the question next and claim the points.

III. <u>WRAP-UP & FIELD TRIP REMINDERS (10 min)</u>

Thanks for playing! (comment on commendable things, if desired: groups that worked well together, class efforts to tackle larger questions in pieces, unexpected and unique answers).

Remember that on __________ *(insert date), we'll be seeing you on the field trip!*

a. *If you haven't gotten permission slips yet, you will be getting those soon, so make sure you give them to your parents to sign.*
b. *Things you should bring if you can: hats, sunscreen, water, and a lunch (unless you get hot lunch, in which case the school will be sending lunches).*

c. *Wear clothes that you can walk around for a while in, and get dirty (sturdy shoes, long pants, etc.).*
d. *Last but not least, remember that nature reserves are special places where people can walk but they have to be extra careful to not litter or damage the environment. So, come prepared to be observant and respectful of your surroundings.*

IV. EXPERIMENT BREAK-DOWN

Pick up materials from plant growth experiment, plus binders.

SAMPLE JEOPARDY CATEGORIES AND QUESTIONS

	Scientific Method	Plant Power	California Habitats	Your Awesome Experiment!	Graphs 'n' Averages	Meet the Volunteer
100	What is a hypothesis?	What are 3 things plants need to grow?	*(grassland photo)* Make 2 observations about the habitat in the photo	What were the 2 soil types in our experiment?	*(pets graph)* What is the y-axis on this graph?	What kind of animal does Thor study?
200	Why do we measure in centimeters and not inches during experiments? *[ans: international standard, it's what scientists use everywhere]*	What is it called when a plant first starts to come out of the soil? *[ans: Emergence]*	What are 2 ways that serpentine soil is different from loam/organic soil? *[possible ans: rocky, heavy metals, toxic to plants]*	What was the research question in our experiment?	*(Mauna Loa graph)* How much CO_2 was there in the atmosphere in 1985?	Name 3 UC Davis teachers beside the ones here today.
300	In our experiment (and others), why was it useful to take averages? *[ans: to help summarize data. If you height for 300 plants, it would be easier to look at 1 graph with 1 trend instead of 300 graphs trends]*	What is photosynthesis? *[possible ans: process of plant making food for itself; when a plant uses sunlight to make energy]*	*(grassland photo)* What would you call the habitat in this picture? (What kind of ecosystem?) *[ans: it's in their notebook. Native Grassland or something like that]*	Explain the method we used to measure our plant heights. 4 steps minimum. *[ans: must describe matching the top/end of the plant to the ruler in cm. It's okay if the last step is recording the data]*	*(Empty graph)* Make a graph for the following plant data: (0.0), (7,3), (14,22)	What does Allie study?
400	If you wanted to know if loud noises bother fish, how might you design an experiment to figure it out? *[ans: make sure they include a comparison between volumes]*	What are the three products of photosynthesis? *[ans: it's in their notebooks. O_2, H_2O, and sugar]*	What is the name of the reserve where we will go for the field trip?	How did you use your data to answer the research question? *[ans: must mention a comparison]*	If Anna is 60 inches tall, Elsa is 66 inches tall, and Olaf is 30 inches tall, what is their average height?	What kind of animal does Lauren dissect in order to study their parasites?

Extra questions, if the students have been on the field trip already:

Category: Field Day	100: Name 3 things you observed on the hike while visiting McLaughlin reserve	200: What was Moria (the scientist you met in the field) looking for?	300: Many of the of the insects you saw at the aquatic station were larvae. Do these organisms live their whole lives in the water?	400: What is this diagram called, and what do the lines/connections mean? *(draw a diagram of a food web, with a few different predators and prey)*

Assessment for Lesson 9

This assessment should be based on the Jeopardy answers, and how it is carried out depends on how the game is conducted. Suggestions:

1. Volunteer instructors sit together after every class and quickly run through the questions with each other, to assess how the class did as a whole.

2. Volunteer instructors obtain permission from teachers ahead of time to voice record the class, so that they can assess answers in more detail. At the start of the game, UCD instructors have students list their names on a team "name card" so that groups can be tracked, and UCD instructors vocally call groups and points very clearly throughout the game so that the voice recorder picks up who is providing answers.

3. The Jeopardy game is run like trivia, with answers for each group being written down. This could be done on a single sheet (to be handed in at the end), or on smaller cards (to be handed in as each turn goes by).

4. Add a page to the student notebooks where they can take notes during the Introduction (project summary) and/or during the game.

into discovering science

Lesson 9A: #ActualLivingScientist Mini-Lesson

Overview & Guiding Questions

Many students are unfamiliar with what scientists do on a day-to-day basis, with the range of subjects that scientists may study, with the variety of places they may work, and with the diversity of people who become scientists. In this mini-lesson, students learn more about scientists, from their volunteer instructors to scientists around the world.

- What are some different things that scientists study?
- What are some different tools or techniques that scientists use?
- What are different places where scientists work?
- What do scientists have in common? What is different about them?

Time Required

15-60 minutes

Preparatory Activities

Gather photos or brief videos of scientists in the lab, field, office, or even at home and combine into a presentation. Try to get a large diversity in field and type of science and in the identities of the scientists. You may focus on scientist volunteers who are present or whom the students have met and/or include scientists from around the world (search the #ActualLivingScientist hashtag on Twitter for ideas).

Supplies

- Photos and videos submitted by scientists or gathered from the internet.
- Portable scientific tools or other props.

Classroom Activities

With the help of photos, videos, and other media, students get a better picture of what scientists do. Using a presentation and a question and answer session, students learn about a variety of scientists.

Objectives

Ecological Understanding

- Students will be able to describe research in several fields of ecology and/or other sciences

Scientific Process

- Students will be able to identify different types of scientific careers and describe some possibilities for what day-to-day scientific activities might entail.

Sense of Place

- Students will learn about scientists studying the students' home environment and/or scientists studying their own home environments around the world.

LESSON PLAN OUTLINE

I. INTRODUCTION (5 MIN)
II. PRESENTATION (10-55 MIN)
III. DISCUSSION (5-10 MIN)

Adapt This!

- This lesson can be long or short, with just photos or videos, props, and other media. Incorporate local scientists or those that may be of interest to your students.
- This lesson can be used to introduce individual projects where students research or interview scientists.
- Some teachers have created #ActualLivingScientist displays in their classrooms, featuring posts from the hashtag.

LESSON PLAN

I. **INTRODUCTION (5 min)**

a. *During our first lessons, we talked about what scientists did and some things that they studied. Let's review some of the things we came up with. What are some things scientists study? Where might scientists work?* (Create a list on the board.)

b. *How many of you have met a scientist before (outside of this program)? Have you read about scientists or seen them on TV or internet? What do you remember about them?*

c. *We've brought a lot of scientist volunteers to meet you so far, and they've all introduced themselves by telling you a little about what they do. But we've spent most of our time working on our experiment, so we haven't spent very much time telling you about what we do, so we want to share a little more today, with the help of pictures and videos.*

d. *One thing you might not know about scientists is that lots of them use Twitter and other social media today! They do this to talk to each other and to share what they do with non-scientists. Last year, a scientist on Twitter realized that many people didn't know any scientists, so he decided to "introduce himself" on Twitter, and lots of scientists followed, using the #ActualLivingScientist hashtag.*

e. *Today, we're going to share photos from our scientist volunteers as well as some from scientists around the world who shared their stories on Twitter.*

II. PRESENTATION (10-55 min, flexible)

a. Go through the materials you've prepared, sharing whatever details you have about each scientist you profile. Information can include where the scientist is from, what questions they are trying to answer, where they work, what kind of environment they work in, what tools they use, why they are interested in that field, and non-science hobbies or interests. Ideally, a scientist presents material about themselves, but don't let this limit the scientist stories that you share.

b. End with a slide with a compilation of #ActualLivingScientists tweets and images to emphasize the limited nature of the presentation.

III. DISCUSSION (5-10 min)

a. *Did you learn anything new from the presentation about things scientists study or places they work?*

b. *Did anything surprise you about the scientists you saw?*

c. *What do you think these scientists have in common? What was different about them?*

d. *Did anyone see anything they thought was especially cool? Does anyone think they might enjoy doing what any of these scientists do? Why or why not?*

Assessment for Lesson 9A

While there is no assessment directly associated with this lesson, a good assessment for this lesson is the Draw-A-Scientist Test (DAST)(see here for an example of this activity: https://www.calacademy.org/educators/lesson-plans/draw-a-scientist). In the KiDS program, the DAST has historically been used before the first lesson in the program and after the last lesson of the program, rather than in conjunction with a specific lesson about what a scientist looks like. However, the DAST (used either before and after or just after the lesson) would be an interesting assessment for Lesson 9A, especially f Lesson 9A is used on its own.

KIDS into discovering science

Special Feature: Fire in the Environment

Overview & Guiding Questions

Students are introduced to fire behavior and ecology principles using an approach that and teaches students the skills to analyze the role of wildfire in different habitats, from how it moves through vegetation to how plant, animals, and people adapt to fire in the environment.

- What is fire and what causes habitats to burn?
- How does the role of fire differ in different habitats?
- How does fire move in different landscapes?
- How do plants, animals, and people adapt to life in fire-prone environments?

Time Required

80 minutes

Preparatory Activities

None

Supplies

- Photos for SmartBoard
- Toothpicks (3 per student)
- Gumdrops (green for fuel, yellow/orange for heat, blue/whatever for oxygen) or marshmallows
- Small ball
- Tree fire scar wedge, seeds, or other hands-on displays

Classroom Activities

The lesson begins with a class discussion and reflection on the role of fire in our lives and on the environment, with a focus on any recent fires in the area. Students learn the chemical reaction for fire and the three ingredients needed to create a fire with a hands-on activity. Next, students use their knowledge from the first section to explore how fire moves in different habitats with an interactive game. Finally, students learn about adaptations and tools for living in fire-prone environments with the help of photos and interactive displays. The lesson concludes with journaling and reflection time.

Outcomes

Ecological Concepts

- Students will be able to identify the three points of the fire triangle and describe how they may vary in different habitats.
- Students will be able to describe how fire spreads differently depending on the vegetation in different environments.
- Students will be able to identify different human, plant, and animal adaptation strategies

Scientific Skills

- Students will practice observing how different habitats have different types of fire.

Sense of Place

- Students will learn about fire regimes in local habitats and discuss recent changes to their home environment.

LESSON PLAN OUTLINE

I. INTRODUCTION (10 MIN)
II. WHY DO THINGS BURN?(20 MIN)
III. FIRE IN DIFFERENT HABITATS (20 MIN)
IV. LIVING WITH FIRE: PLANTS, ANIMALS, AND PEOPLE (15 MIN)
V. WRAP UP AND HANDS-ON STATION (10 MIN)

LESSON PLAN

Adapt This!
If wildfires have occurred recently in the region where the students live, focus on those fires and the kinds of fires that occur in local environments. Take care to be sensitive when discussing destructive fires. In a community affected by recent wildfire, discuss the lesson with teachers in advance and ease into the lesson with journaling and group discussion.

I. Introduction: Why study wildfire? (10 minutes)

a. Next week, we'll visit McLaughlin Reserve (where is it? What will we do there? Answer a few field trip questions). This is a really interesting year, because of the two big fires that burned there this summer. It will look really different than it did last year. **Has anyone noticed how places around here have changed?**

b. When a fire happens, it causes big changes, for people and the environment. When there is a big change in the environment, scientists call this a "disturbance". A disturbance is temporary, but it can take a long time for a place to get back to the way it was! **Can you think of any other things that cause big changes in the environment in California? (Answers: earthquakes, floods, climate change, drought, animals, people). What about in other parts of the country? (answers: hurricanes, tornadoes).**

c. **Why do you think it is important to study big changes (disturbances) like wildfire?** Take a few minutes and talk to your neighbors.

d. Big changes like fire can create big challenges for people and the environment. We ask questions so we know better what to do to protect ourselves and our homes and to understand how it affects the plants and animals that live around us. We study fire with science to understand it—when you understand how it works, you can better understand how to make tricky decisions about how to live in a place where stuff burns. Fire can be useful—for cooking, but also for clearing land, reducing risk, putting nutrients in the soil—and people have used it this way for a long, long time. Fire is kind of like water—sometimes it is good, sometimes it is bad. The challenge is understanding how it works, and how to live with it.

e. We can break this down into three questions:
   i. Why do things burn?
   ii. Where, when, and how do they burn?

iii. What are the effects on plants, animals and people, and how do they deal with it?

II. Why do things burn?: The Fire Triangle (20 minutes)

a. The first thing you need to understand when you study fire is why it happens. Fire is a chemical reaction. **What other chemical reaction did you study in this program (Ans. Photosynthesis)?**

b. The reaction for fire is kind of like the opposite of photosynthesis. Photosynthesis builds plant material, and fire breaks it down (respiration does this too).
When fires burn, you have:

Carbon (usually plants!)+ oxygen + heat → heat + light + $CO2$ + water
Photosynthesis was $CO2$+ water +light → sugars (carbon in plants!) + $O2$ + water.

c. Every question in studying fire comes down to something called the Fire Triangle. We're going to make "fire triangles" to help us understand the ingredients for a fire.

d. Everybody will get 3 toothpicks and 3 gumdrops. We'll use these to make a triangle—one gumdrop connecting each corner. Draw a triangle on the board and use to illustrate.

e. Each corner represents one ingredient you need to make a fire. Just like when we studied what plants need to grow, a fire has ingredients. **Has anyone ever built a campfire? What did you need to make a fire? (Ans: heat, fuel, oxygen).**

f. We need 3 things to have a fire:
  i. Fuel. Fuel is the stuff that burns. It can be wood, it can be grass, it can be coal or oil. Fuel is usually made up of carbon.
  ii. Heat. We need heat to make the fuel hot enough to ignite the reaction. If the fuel is wet, you need more heat for it to ignite. Once the fire starts, the heat it produces keeps the fire going. Heat can come from lightning, or electricity from humans, like powerlines, water heaters, cars, or an existing fire, like a campfire or a cigarette.
  iii. Oxygen. The reaction requires oxygen to burn. Have you heard of stop, drop, and roll, or covering up a fire with a pot? Fires can't burn without oxygen. And adding oxygen, like when you blow gently on a campfire or add wind, can make a fire bigger.

Each of these ingredients is one corner of the triangle.

Triangles are really strong, but every corner is important! This is true of the fire triangle, too. Fires can be really powerful and cause big changes. **But what happens if you eat one of the gumdrops? (Ans: it falls apart).** If you don't have every ingredient, you don't have a fire.

III. Fire in Different Habitats: where, when, and how do things burn? (20 minutes)

a. *Now that we know why things burn, we have the tools to figure out where, when, and how things burn. Do you think fire burns the same way in different places? Why or why not?*

b. Fire burns anywhere and anytime you have enough heat, fuel, and oxygen. But you get different amounts of fire in different places depending on how much heat, fuel, and oxygen you have, what kind of fuel you have, and how often you have all of the ingredients.

c. *Let's start out easy. Which place do you think has more fire, the Arctic tundra, or California? Why?* (Ans. CA is hotter, more plants). *Now let's make it trickier—desert or rainforest?* (Ans. Desert is hot, but not enough plants. Rainforest is hot and has plants, but it's too wet. Both burn pretty rarely.)

d. *We're going to observe habitat pictures like you saw in our first week together, and we're going to try to figure out how much fire is there. Think about how much heat, fuel, and oxygen there might be. How often do you think it burns?* Show 3 photos: blue oak woodland, chaparral, Jeffrey pine forest (2 photos are the same as first week).

Adapt This!
Use photos of local environments (ideally, the same ones from Lesson 1), and/or compare and contrast with environments from other regions.

These are all in California. Here, we have cool wet winters and hot dry summers, so there is lots of fuel, and it gets very hot and dry in the summer. Most fires happen in the late summer. These places burn differently mostly because of the kind of fuel (plants).

Let's act two of these out to figure out how fire moves here.

e. **Activity:** Get 5 volunteers (can include the teacher or instructors). People are the plants. The ball represents the fire. Standing up you are a tree, crouching you are a shrub, sitting you are grass or pine needles.

   i. Blue oak woodland or Jeffrey pine forest. Three kids sit, two people stand on either end. Try to pass the fire ball along the line without unbending your elbows. Can a grass pass to a tree? What if there is a shrub (one person next to a tree kneels)? What if there is no fire for a long time, and there are trees in the middle (everybody stands up)?

ii. Chaparral. Everybody is a shrub. Is is easy to pass the fire?

Let's go back to the pictures. Guide students to the story.

i. Blue oak woodland. What kind of fuel is there (grass, a few trees)?
ii. In the blue oak woodland, the grass burns very easily because it dries out quickly and it gets hot because there isn't much shade. The fire is very low to the ground, and the fire passes by quickly. The oaks might burn, but they do not catch on fire as easily as the grass. Bark is thick, and it's hard for the fire to get up to the leaves. Fires happen pretty often, making it hard for new seedlings to grow into trees.

iii. Chaparral. Chaparral has LOTS of fuel, and it is well above the ground. Not much grows on the ground below the shrubs. It doesn't dry out as easily as grass, and it doesn't burn as easily. But when it does burn, it's very densely packed. It burns very hot, very intensely, and fire spreads very easily. Fires last longer and are much harder to stop than in grass. Fire doesn't happen as often here, and the fires are big.

iv. Jeffrey pine forest. There are pine needles on the ground, which dry out easily. There are some big trees, but it would be hard for a fire to move up to the top of the tree. Fires burn pretty often here, but usually the big trees survive, like in the oak woodland. Fires happen pretty often, making it hard for new seedlings to grow into trees.

Bonus: Do you think fire might burn differently in serpentine or non-serpentine soil? Why? (Possible ans.: more fuel on non-serpentine, more fire.). Do you have any other ideas of patterns we might see at McLaughlin?

IV. Living with fire: how do plants, animals, and people respond? (15 minutes)

a. We saw in part 1 and part 2 that fire will happen if you have the 3 ingredients, and that fire happens in different ways in different places. The heat and smoke from fire can hurt all kinds of living things. Plants, animals, and people live in places that burn, so what can they do to deal with it?

b. There are 2 strategies:
   i. You can resist the fire. If the fire is weak enough or you are strong enough, you can resist the fire or stop it from spreading. This is what people generally do, and lots of plants and animals do this, too.

Examples (show photos):

- The blue oaks have thick bark to protect their trunks from fires in the grass, so they usually are not killed by fire. If they are damaged by the fire, they store nutrients underground and can resprout.
- Many of the shrubs we see have parts of the plant underground. If the parts we can see burn, they resprout and grow back quickly.

Adapt This!
- Focus on local adaptations and tools, but compare and contrast with other environments.
- In some regions (e.g. the Southeast), consider greater focus on the role of prescribed fire.

- Jeffrey pine trees self-prune. They drop their lower branches so fire doesn't carry from the ground to the top of the tree to kill it.
- Jeffrey pines also have thick bark (see tree wedge with fire scars).
- Animals burrow into the ground or move away from the fire.
- People clear brush away from their houses, clear area by burning, build houses out of non-flammable materials, put fires out (but what happened when there was no fire in our people-forest?).

ii. You can take advantage of the fire.
If you can't resist the fire (or even if you can), you can use the big change for your benefit—or your children's benefit. Remember how we said fire was the opposite of photosynthesis? When fire happens, all of the nutrients that went into building that plant are released into the soil and air—like recycling. Lots of light and space are available. It's a great time to be a baby plant, and for animals that can use young plants or the parts of plants that are left behind.

Examples (show photos):
- Seeds and pinecones open or germinate in response to heat or smoke. It's a signal that it will be a good time to germinate soon.
- Lots of wildflowers only flower for a few years after a fire. We should see a lot of pretty flowers next week!
- Black backed woodpeckers make their homes in dead trees.
- People use fire to clear land, improve growth of plants, control invasive species, and reduce fire risk. Native Americans have long used fire to cultivate plants for basket weaving in California. Researchers think that many of the habitats we see today, like oak woodlands and grasslands, exist because humans have burned them for thousands of years to keep trees from taking over!

V. Wrap Up and Hands-On Station (10 minutes)
In the last 10 minutes, we'll take a few minutes to write in our notebooks about wildfire. It can be a scary subject, but it's important to learn about. Think about these questions:

- What do you think about when you hear the word wildfire? Draw a picture.

- Did you learn something new today? What was it?
- Why do you think it is important to study fire?
- What do you think we'll see when we visit McLaughlin reserve next week?

While you are writing or drawing, each table will come up, one at a time, to look at the "tree cookie" from the pine tree that has survived hundreds of years of fires and other displays.

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Field Trip

Overview & Guiding Questions

Students go on an all-day field trip to a local reserve, where they hike, examine aquatic invertebrates, study food webs, and re-enact a local field experiment.

- What do you observe in your local environment? How do we observe our environment?
- What kinds of habitats do you see? What plants and animals live in different habitats?
- What patterns do you notice in the environment?
- How do food webs work, and how do environmental factors shape food webs?

Time Required

4 to 5 hours

Supplies

- Nametags
- Station signs
- Schedules
- Snacks
- Station supplies (see station supply lists in station lesson plans)

Preparatory Activities

- School Logistics: Permission forms (including photo permissions), transportation, chaperones.
- Have teachers assign students to small groups.
- Assign volunteer roles (group leader, station teacher, photographer) and train station teachers.
- Print nametags and gather supplies.
- Set up signs at site.
- Identify and pre-walk hiking route.
- Collect aquatic invertebates.
- Choose location for Food Web Station and set up plots.

Activities

Students visit a local reserve, moving through 3 stations in small groups: a hike centered on observation and habitats, an aquatic invertebrates station that looks at animal traits and behavior up close, and a food webs station focused on food web function and field experiments. Students also have the opportunity to ask volunteers questions about their work.

Objectives

Ecological Concepts

- Students will be able to describe different types of plants and animals and the habitats where they are found.
- Students will be able to describe how plants grow differently on different soil types.
- Students will be able to describe different types of invertebrates found in aquatic environments and how they move in water.
- Students will be able to describe how plants and animals are connected in a food web.
- Students will be able to describe how predation success can vary in different environments and how soil can affect interactions between birds and their prey.

Scientific Process

- Students will practice making observations of the environment outside in the field.
- Students will learn about and try out basic field tools.
- Students will be able to describe why and how ecologists do experiments in a field setting.

Sense of Place

- Students spend all day exploring their local environment.

Field Trip Outline

I. OVERVIEW AND SAMPLE SCHEDULE
II. STATION 1: TAKE A HIKE!
III. STATION 2: INVERTEBRATE INVESTIGATION
IV. STATION 3: FUN WITH FOOD WEBS
V. MEET A SCIENTIST OPTION

Field Trip Lesson Plan

I. OVERVIEW AND SAMPLE SCHEDULE

The KiDS field trip is the highlight of the entire program. The field trip, to a university-run research reserve near the students' homes, reinforces concepts introduced in the classroom and allows students to explore their local environment armed with their new knowledge and with scientists at their side to answer questions. The trip addresses all three of the program goals: developing scientific skills, sense-of-place, and relationships between a large group of scientists and the students and parent chaperones. Many students thrive on the field trip who struggle in the classroom.

Preparatory activities include recruiting and training volunteers, working out logistics with the reserve managers, working with teachers on transportation and permission forms, organizing materials, and setting a schedule.

Though the schedule changes from year to year depending on class size, volunteer interests, time available, and other factors, the overall format includes an introduction, three or more stations that groups rotate through, lunch, and wrap up (see sample schedule). Students are divided into small groups of 9-15 students and 1-2 parent chaperones, led by 1-2 volunteer group leaders (see sample group assignments and rotations). Small groups are named for local plants and animals. Each station is taught by a trained volunteer. In order to keep the groups small, we run each station in duplicate at the same time.

The introduction should be very brief, so that students get into their groups and on their way for the day. The wrap up timing will depend on whether you are on schedule by the end of the day. One approach is to have each small group discuss and share with the larger group 1) the coolest thing they saw that day, and 2) the most interesting they learned that day.

In some years, we have added a "Meet the scientist" activity, where students can ask scientist volunteers any questions they like. The three stations described below have been successful components of the program for several years, but the model is sufficiently flexible to add new stations or add content to pre-existing stations based on volunteer expertise.

Sample Schedule

Time	*Activity*	*Description*
8:15am – 8:45am	Station set-up	Station leaders set up. Group mentors meet with Field Trip Coordinators for nametags
8:50am – 9:30am	Buses arrive, Groups walk to 1st station at 9:30am sharp	Introductions, Divide into groups, Bathroom trips, Icebreakers
9:40am – 10:10am	Station 1	See rotations below
10:20am – 10:50am	Station 2	See rotations below
11:00am – 11:30am	Lunch	Meet at communal picnic tables
11:30am – 11:50am	Meet the Scientists!	Q&A sessions in mentor groups
12:00pm – 12:30pm	Station 3	See rotations below
12:40pm – 1:00pm	Closing remarks, Evaluations	Groups meet at buses. Mentors should review activities with students and pick one thing to share. Big sharing circle.
1:00pm	Buses load up and depart	Everybody wave!
1:00 – 2:00pm	Station clean-up	Including trash pick-up

Sample Group Assignments and Rotations:

Volunteer Group Leader	Student Group Name	Station 1	Station 2	Station 3
Grace	Clarkia	Invertebrates 1	Hike 1	Food Webs 1
Eric	Woodpecker	Hike 1	Food Webs 1	Aquatic 1
Clark	Bumblebee	Food Webs 1	Aquatic 1	Hike 1
Eduardo	Black Bear	Aquatic 2	Hike 2	Food Webs 2
Jessica	Hawk	Hike 2	Food Webs 2	Aquatic 2
Kelly	Mountain Lion	Food Webs 2	Aquatic 2	Hike 2

II. STATION 1: TAKE A HIKE! (20-30 min)

Overview: The hike is designed to be a relatively unstructured activity, allowing students to explore their local environment freely. The goal is for students to apply concepts they have learned in the classroom (observation and the scientific process, habitats, soil science, plant biology, etc.) to understanding their local environment. The hike leader should encourage students to call out their observations and ask questions. The hike should have a predetermined route and the hike leader can plan discussion topics around that route, but ultimately the students' interests should guide the discussion.

Materials: The hike can be successful without any supplies, but consider bringing field supplies like hand lenses, binoculars, measuring tapes, or a small quadrat. Small notebooks or drawing paper and pencils can work well, too. These supplies should supplement but not distract from free exploration of the environment.

Adapt This!

- Choose a hiking route that can be easily completed within the allotted time, taking into account extra time for many stops and observations.
- Try to choose a route that includes many different habitat types and demonstrates concepts from the classroom.
- Choose hike leaders who know the environment well, ideally those who have done research in that location.

Activities:

The following is a list of potential discussion topics to guide the hike. Many of these topics tie into themes from the longer course curriculum.

- Use Your Senses: Introduce the hike by encouraging students to look up high, look down low, listen, and touch plants, soil, water, and other things they find (warn about hazards; use discretion when encouraging smelling and tasting). Have students make observations about what they see.
- Kinds of Habitats?: Review the definition of a habitat, and encourage students to point out different habitats they see (e.g. pond, forest, meadow). What plants or animals might live there? What traits might plants and animals have that help them live in that habitat?
- Compare and Contrast Across Landscape Boundaries: When crossing over a boundary of some kind (e.g., different soil types, burned vs. unburned, grassland vs. forest), discuss how plants diversity differs across the border. What might cause the difference? You can use a quadrat to estimate plant diversity on both sides of the border.
- Field Science and the Research Process: Talk about field research versus a lab experiment (or their classroom experiment). Why might you do a field experiment? What would the drawbacks be? Describe any field experiments that you can see, if you are in a research reserve. Demonstrate the use of any field equipment you've brought. If

possible, have a scientist who actually does research in the area stationed along the hike route for students to "run into."

- Animal Tracks: Discuss any signs of animals, including footprints, scat, herbivory, or nests.
- Climate Change and Wildfire: Discuss signs of any big changes on the landscape, such as drought or fire. Use before/after photos to show what the landscape looked like at another time. How is this landscape changing, and how will that affect the plants and animals?

III. STATION 2: INVERTEBRATE INVESTIGATION (20-30 min)

Adapt This!

- Almost any body of water will have lots to see, including ponds in city parks.
- Consider incorporating terrestrial invertebrates.

Overview: Like the hike, this station is designed to encourage students to explore and make observations. While the hike focuses on different habitats, this station gives students a closer look at invertebrate animals from aquatic habitats. Students use hand lenses and small tools to observe what invertebrates are found in local ponds and streams, how they move, and how they interact. Students can try to identify what they see. If the space allows, students can also learn how to collect aquatic invertebrates. Because this station involves live animals, station and group leaders should keep a close eye on the students and make sure they are treating specimens and equipment with care.

Materials:
This station requires collecting specimens in advance.

- Shallow trays for viewing specimens
- Hand lenses
- Forceps
- Species ID sheets and/or simple dichotomous keys
- Dip nets and/or plankton nets

Activities:

- Begin by introducing some of the specimens on display and demonstrating proper use of lenses and other tools.
- Guide observation with discussion questions such as:
  - What do you observe about this animal? How many legs does it have? How does it move?
  - Where in the water do you think this animal lives and why?
  - What do you think this animal eats? What do you think eats it?
- If a station teacher has particular expertise in an animal group, the discussion can be more focused. For example, this station had a nematode focus in 2016, and the station was supplemented using skins of animals that nematodes parasitize.

- If supervision and space allows, demonstrate how the specimens were collected using whatever tools you have.

IV. STATION 3: FUN WITH FOOD WEBS (20-30 min)

Overview: This station is the most structured and is divided into two interactive games that demonstrate principles of food webs and predator-prey dynamics as well as field ecology. Students explore how food webs work and the roles of camouflage and habitat in food web interactions. Students 'recreate' a real field experiment that took place at the reserve they are visiting.

Materials:
- Food web cards with pictures of local plants and animals (attached to yarn and worn like a necklace)
- Yarn ball
- Signs or posters that illustrate the original experiment
- 50 clay caterpillars
- Dowels and string to mark off plots

Adapt This!
- Choose local plants and animals for your food web cards. We use local wildflowers and mountain lions.
- The caterpillar/birds experiment can be done on different soil types, in two bordering habitats, or on burned and unburned soil.
- Learn about past research at your field trip site or nearby and create your own activity based off of real experiments.

Prepare by marking off two small, square plots, one in serpentine and one in loam soil. Divide the caterpillars into two groups and scatter each group in one plot.

Part 1:
Introduce the concept of a food web. What do the kids think this means?
To illustrate, play the food web game. Each kid gets an animal/plant food web card. Starting with a card at the lowest trophic level, have the students pass the yarn through the links of the food web by tossing the yarn ball to someone that would eat them, forming a chain or web. What do the kids observe about food webs?

Part 2:
In this section, students learn about how scientists might study food webs and the habitats they exist in by recreating a real experiment. Discuss the 'caterpillar experiment': scientists at UC Davis wanted to test whether caterpillars were more likely to get eaten by birds on serpentine vs. loam soil. They scattered clay caterpillars on both soil types and then observed which caterpillars had more beak marks from birds.

Review related concepts from the classroom: What did you learn about serpentine vs. loam soils? Where do you think the caterpillars got eaten more in the experiment? Why?
(Ans: more plants in loam, caterpillars blend in, but on serpentine, they are more exposed, and birds find them more easily).

Let's recreate this experiment. We've scattered caterpillars in both soil types. Split the group in two (1 group / soil type) and see how many caterpillars you can find in 1 minute. Tally the caterpillars found on paper. If there's time, re-scatter the caterpillars and switch soil types.

Discuss results. Are caterpillars easier to find in serpentine or loam soils? Do these results agree with what the scientists found? Why or why not?

V. Meet a Scientist

Overview:
This activity provides a time for students to ask questions of their volunteer instructors that couldn't be answered during the classroom sessions due to limited time. Volunteer instructors introduce themselves and often their research interests during classroom sessions, but there is little time to discuss sharks, parasites, or gorillas (to name a few popular examples!) in the classroom. This activity can fit in after lunch or at the end of the day. This activity is not a presentation, but a free time for questions.

Materials:
None. Volunteers may choose to bring field equipment or photos to show the students, but showing these things should not take time away from free question time.

Activity:
Select three volunteer instructors with exciting research areas (or those who have a talent for making their research accessible and exciting). You can also group instructors with similar research areas.

Gather students into three groups (it can work well to combine their smaller groups for the day), separated enough that it's easy to hear students and instructors within the group but close enough to walk between quickly.

Divide the allotted time into three (we used a 30 minute period, 10 minutes for each station). Station a volunteer instructor at each larger student group. Have the instructor introduce themselves and their research area briefly (2-3 minutes maximum), then open the floor to student questions for the rest of the time. When the time is up, have instructors rotate between student groups until each group has had time with each volunteer instructor.