CO2 LEARNING CENTER

Book Five Lesson Plan

The Mystery of the Night Raiders

This lesson plan was produced by the CO_2 Learning Center, a project of the CO_2 Coalition, and meets the Next Generation Science Standards for Grades K – 8.

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A note about our lesson plans:

Our CO_2 Learning Center lesson plans all have the same format, which include student learning objectives, background information on the science concepts covered in the book or video, suggested activities including labs to enrich the lesson and reinforce use of the scientific method, formative and summative questions, and learning standards from the Next Generation Science Standards (NGSS).

This lesson plan was created by the CO_2 Coalition's Senior Education Advisor Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).

The NGSS are the standards on which most public-school systems have based their curriculum. We do not necessarily endorse the NGSS but have included the relevant standards for circumstances in which a teacher is required to use them. The lesson plans contain everything that a teacher might be required to submit in a formal lesson plan to a school administrator or science department head.

Understanding NGSS:

LS: Life Science

PS: Physical Science

ESS: Earth and Space Science

ETS: Engineering, Technology, and Applications of Science

1-5 indicates standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

Please note that for Book Five, grade-specific NGSS standards are included for Grades K, 2, 4, 5, and MS. Only the parts of the standards that are relevant to this lesson have been included. If LS and PS only (example from this lesson) are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.

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Lesson Plan: Book Five

Grades K-8

Student Learning Goals

After reading the book, students will be able to:

- Explain what the scientific method is and list the seven steps
- Give two characteristics of a good scientist
- Explain the goal of the scientific method
- Describe different types of evidence and rank them by quality
- Explain what differences there may be in the type of data collected
- Explain how the scientific method can be used for solving problems that aren't scientific
- Explain why data is more important than opinion when using the scientific method

Background Information

The scientific method is a process that is first associated with the ancient Greeks about 3,000 years ago, used extensively by Sir Issac Newton, and has been perfected over time. The main steps of the scientific method are:

1) **Ask a question.** Perhaps an observation is made that encourages questions, such as how does this work or why does this happen, or even what causes this situation.
2) **Gather background information.** Is this a question that already has an answer, or is it a new question? What has already been discovered that would help answer the question?
3) **Make a good guess (hypothesis) as to the best answer.** The investigator should decide what the most likely answer to the question will be. This is called a hypothesis.
4) **Perform experiments or <u>make observations</u> to test the guess; repeat until it is certain the results are correct.** This is the hardest part of the method because designing an experiment that answers the question asked is a lot more complicated than it sounds and requires most of the time to design when trying to find an answer to a question. Once an experiment has been designed, it should be repeated to make sure the results weren't a one-time result. Sometimes hypothesis testing involves making direct observations. An example would be geology, where learning about ancient events involves observations and not necessarily experiments.

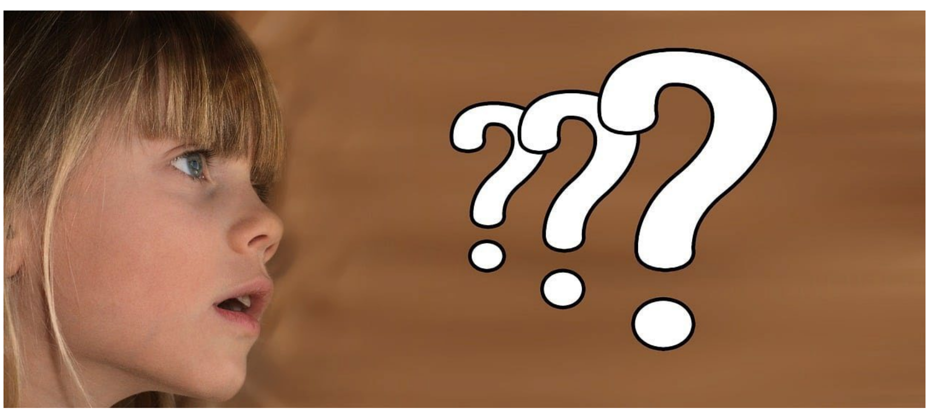
5) **Analyze data from the experiments.** The data can be analyzed in several different ways, including graphing, tabulating, and statistical analysis, depending on the type of data.
6) **Draw conclusions.** An honest experimenter will take all the available data to draw conclusions, and not just the data that might have been expected by the experimenter.
7) **Share results with others.** New information can be shared with others in the form of a presentation or a report.

Each of these steps will be discussed in more detail below. The above steps are the simplest interpretation and can be easily adapted for very young children who are natural investigators. The educator can guide them to answer simple questions about the world around them. A simple example would be to ask the students what they expect to happen when two golf balls collide with each other. The answer will be different depending on the angle of impact. By having the students set up an experiment to find the answer, they are using the scientific method in a simple but effective way.

Older students, such as middle school or high school grades, should be able to use the scientific method in a more sophisticated way. For them, the steps above need to be more precise.

Discussion of Scientific Method

1) **Ask a question.** The instructor will usually set the parameters for the question. For example, the instructor may tell the students to find out something about plant fertilizers that the students don't already know the answer to, such as compare fertilizer brands/types instead of asking if fertilizer makes a plant grow faster.

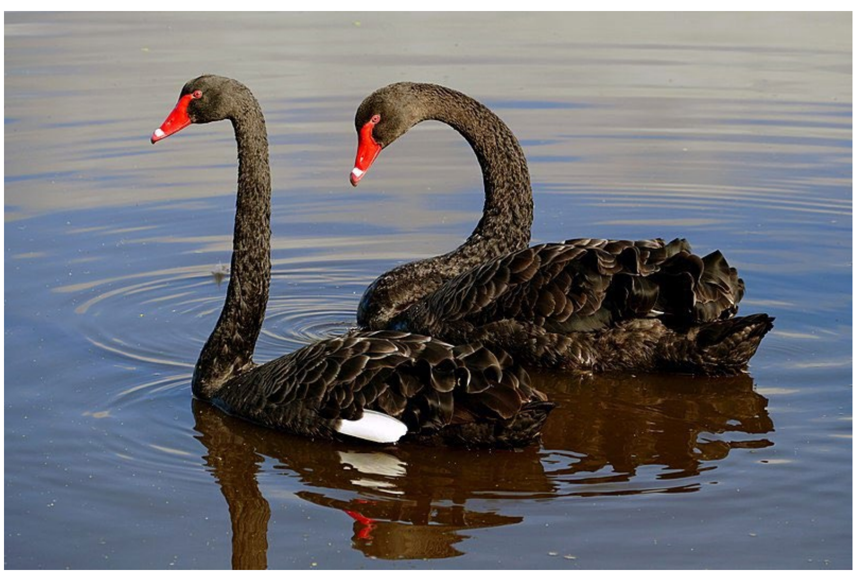


Source: https://pixabay.com/illustrations/question-mark-girl-future-a-notice-2405218/

2) **Gather background information.** Using the example above, perhaps there is already information available that compares the two fertilizer brands. If so, perhaps a different yet related question can be asked. If not, then information on what the contents and percentages of the fertilizers are, whether they are all-purpose or specific for one type of plant (garden vegetables, for example).

Source: https://pixabay.com/vectors/lee-berger-desk-laptop-homo-naledi-978052/

3) **Make a good guess (hypothesis) as to the best answer.** Assume the student decides that the question is "does organic fertilizer Brand X cause plants to grow faster/healthier/taller than inorganic fertilizer Brand Y?" The student can choose a hypothesis that states "Brand X will cause a plant to grow better than Brand Y." The student could also choose the opposite, or the student could choose what is called a null hypothesis, which states "there is no difference." A null hypothesis is usually easier to support or disprove. A hypothesis can never be proved, it can only be disproved or supported. This is a very important point because it acknowledges the fact that more data could be collected in the future which disproves the hypothesis. An example is the color of swans. Suppose the observer has only ever seen white swans, so the observer states that all swans are white. This hypothesis is supported until the observer sees a black swan, at which time the hypothesis has been disproved. For this reason, data are sometimes referred to as a black swan when it disproves a prevailing hypothesis.



Source: Bernard Spragg. NZ from Christchurch, New Zealand, CC0, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:The_black_swan_(Cygnus_atratus)_(33064803230).jpg

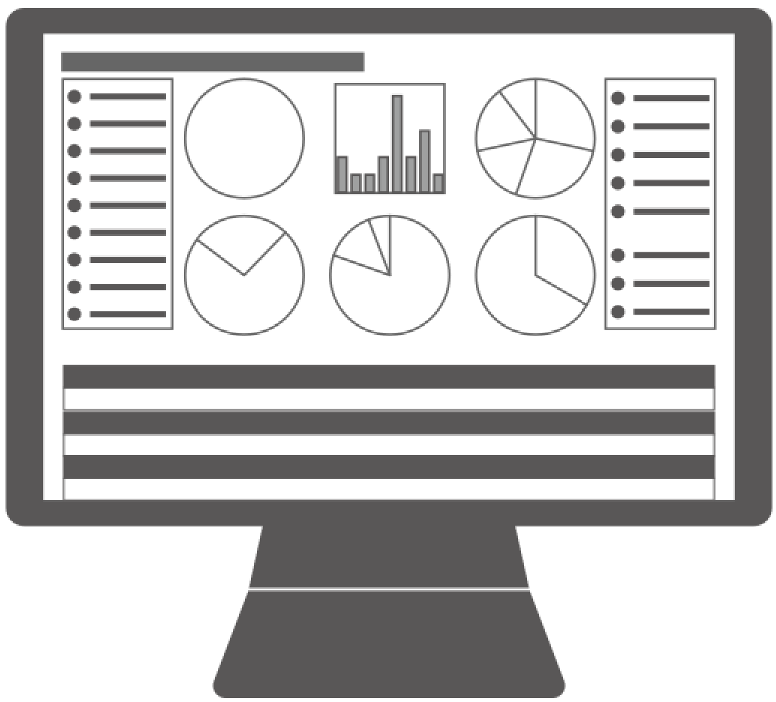
4) Perform experiments or <u>make observations</u> to test the guess; repeat until it is certain the results are correct. Set up replications of an experiment. A replicate is an "independent application of the treatment" within the experiment. So, if there was one control plant and one treated plant in the experiment, that would be one replicate (called an "experimental unit"). If there are two pairs like that, it would be two replicates, etc. For example, perhaps the student wants to test the effectiveness of a specific fertilizer on bean seeds. For each replicate, a new fertilizer solution of the same concentration is made for each control and replicate. This process will allow the experimenter to avoid the mistake of using the same fertilizer solution for the whole experiment if it was mixed incorrectly. The more plants there are with solutions that have been prepared separately, the more reliable the results are. Also, having more plants in each experimental group allows the experimenter to obtain averages of many measurements within the same replicate. The more replicates there are, the more powerful the experiment is.

Source: NASA/Shane Kimbrough, Public domain, via Wikimedia Commons,
https://commons.wikimedia.org/wiki/File:Plant_Habitat-04_experiment_(ISS065-E-235366).jpg

It is also important to note that an experiment must be designed that includes a control, constants and the factor being tested. In this example, the factor being tested is the type of fertilizer, so there would be three experiments running at the same time: one with fertilizer X, one with fertilizer Y, and one with no fertilizer at all. The one with no fertilizer is the control, where everything else is the same except for the presence of fertilizer. This is to allow the experimenter to determine if there are any outside factors that are affecting the results of the experiment, such as uneven lighting or uneven temperature, or if the control plant would grow as well if not better than either of the experimental groups. The constants are everything in the experiment that remains the same, such as the type of soil, the amount of water, the type of bean seed, etc. The seeds with the factor being tested are called the experimental groups, the control group is the one with no fertilizer. These two groups along with all the constants should be identified before the experiment is conducted.

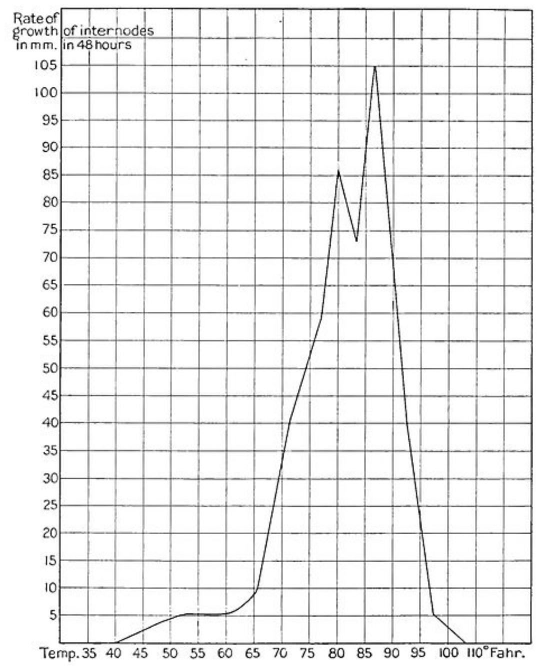
5) **Analyze data from the experiments.** Not all data* is created equally. The poorest data are testimonials, or data that are not empirical. The best kind of data are derived from a controlled and replicated experiment. Two different types of data can be collected from an experiment: qualitative and quantitative. Both can be important in an experiment such as the one in the example, but only one can be presented easily in graph form, and that is quantitative. Qualitative is subjective data; for example, is the plant healthy or sickly? What color is it? Quantitative is objective and consists of measurements; for example, how tall did the plant grow? How many leaves does it have? What is its dry mass? All this data can be analyzed statistically and presented in the form of a graph, whereas qualitative data are best presented in the form of tables.

   **Note: the word "data" is usually considered to be plural, not singular*



Source: DataBase Center for Life Science (DBCLS), CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:201806_DataAnalysis_on_display.svg

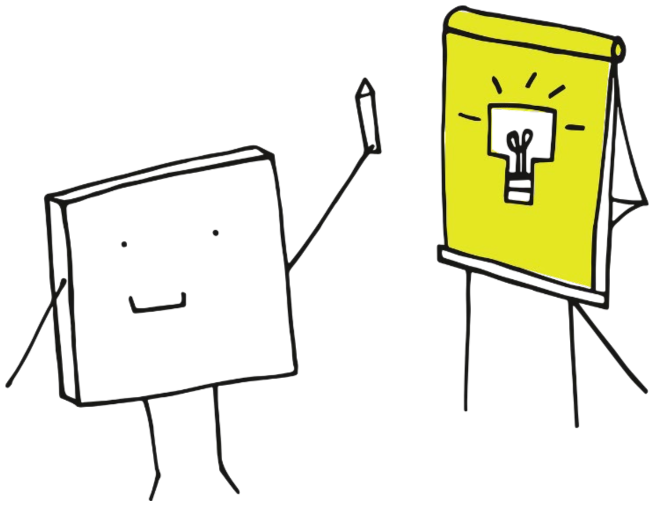
For a graph, the independent variable and the dependent variable should be identified before the graph is drawn. It is traditional to graph the independent variable on the horizontal, or x-axis. This variable is the one that is manipulated by the investigator. For the example given above, the independent variable would be the time interval at which measurements were taken, as each experimental group and the control group all have the type or absence of fertilizer as a constant. In other words, every plant that gets fertilizer X is in the same group, so the type of fertilizer is a constant for that group. However, the experimenter determines how often data will be collected, for example, once a week at the same time of day for three months. The dependent variable is the information that is measured, such as the height of the plant or its dry mass, and this is plotted on the vertical, or Y, axis. For this example, there will be three separate graphs. They can be superimposed on the same axes by using different styles or colors of lines to differentiate them. If many data points have been taken at one time (such as the height of 10 different plants), the average or median value is graphed with error bars. For the purposes of the activities listed here, the error bars and any type of statistical analysis can be left out.



Source: D. T. MacDougal, Public domain, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:PSM_V84_D432_Rate_of_growth_of_seedlings_of_wheat.jpg

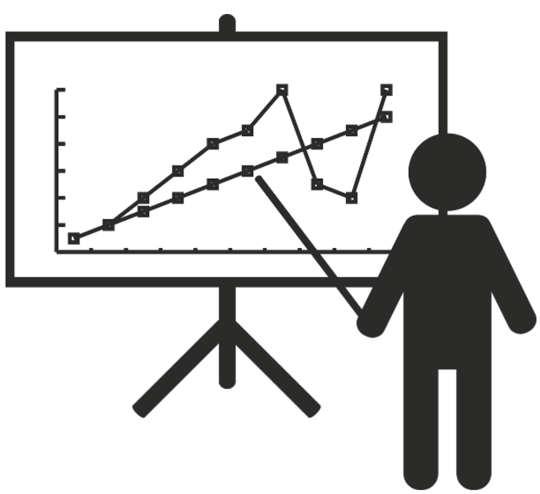
6) **Draw conclusions.** A good scientist should be completely honest and view the study skeptically, even if the same scientist designed the lab and analyzed the data. Sometimes this is the hardest part because frequently an experimenter has previously decided what the outcome of the experiment should be, but the results don't support the hypothesis. This could be because of a bad experimental design or because the hypothesis is disproved. For example, in this experiment, perhaps the experimenter expected a favorite fertilizer to be better, but the results indicated otherwise. Or maybe there was no difference among any of the groups, and the results were the same as the control group. In this case, a student is likely to think that there were no results or that the experiment was bad. Sometimes the experimental design is bad, or there are errors in the measurements taken, or other problems. But sometimes the null hypothesis is supported. Therefore, it is important that the experimenter closely examines the experimental design, makes changes if necessary, and repeats the experiment. It is easy

to make an honest evaluation of the data if there is no bias one way or the other on the part of the experimenter. At the end of the experiment, however, the experimenter should be able to conclude whether the hypothesis was supported or if it should be rejected.



Source: https://pixabay.com/vectors/idea-visualization-line-art-3976295/

7) **Share results with others.** It is important to share the results of the experiment with others. The educator may decide to accept the results in the form of a written report, or a presentation can be made using PowerPoint or another method to outline the entire experiment and show the results in the form of graphs and charts. The complexity of the report should be based on the grade of the experimenter. Older students should be expected to present a high-quality product, whereas younger students should be expected to simply show what they did and what happened.



Source: https://pixabay.com/vectors/presentation-data-office-networking-1559937/

References

1) How to design an experiment: https://www.scribbr.com/methodology/experimental-design/
2) What are the parts of an experiment: https://simplicable.com/science/experiments
3) A Beginner's Guide to Graphing Data: https://youtu.be/9BkbYeTC6Mo
4) Graphing Data by Hand: https://youtu.be/GUYRMdcEs00

Suggested Activities

The following suggested activities range in appropriateness from grades kindergarten to 8th, going from simplest to most complex.

1) **Is It Alive? (For Grades K)** Kindergarteners are just learning how to determine if a substance is living, dead but previously living, or nonliving. In this activity, the students will learn what qualities each of the above have and how to tell the difference. They will then be asked to categorize objects into one of the above three categories and give reasons as to why they determined their answers. Examples of nonliving things include plastics, metals, glass, etc. Examples of previously living things would be wood, cotton, wool, etc. This is a two-part activity; the first part is their "research," and the second part is experimental.

    a. **Part 1: Materials:** A living plant, a dead plant, and a plastic plant in separate pots.

       Procedure: Go over the definitions for living, dead but previously living, and nonliving, then ask the students for examples. Also ask the students how they can tell by looking at something which category it falls into, and what are some general characteristics of all three categories. Then show the students the three plants and have them decide which category each one falls into and why. (To keep students from letting another student decide for them, have them write smiley faces on a piece of paper or a personal whiteboard: smile for living, frown for dead, and blank expression for nonliving. They can write a one-word characteristic of each. Then have the students share their answers. Discuss how the leaves are different on each plant and talk about how the plants are similar and how they are different.

    b. **Part 2: Materials:** Bean seeds (get these from a garden center and not from a grocery store; the ones from the grocery may not be viable), paper towel (absorbent paper towels are better than the unabsorbent brown ones), plastic baggies, light source. Mung bean and lima beans work well.

       Procedure: Give each student several bean seeds. Ask the students if the beans are living, dead, or nonliving, and ask them how they could find out. Their first answers are their hypotheses, and the second answer is their experimental plan.

All the answers could be written on the board so that the class could pick the best experiment. Give the students the paper towel and the plastic bag, and have the students guess what they would expect to see if the seeds were alive and if they were dead. Show the students how to “plant” their seeds using the paper towel dampened with water and the bag. The bag should be hung in a place that gets bright but indirect light. Have the students look at their seeds every day and record their results by drawing pictures. At the end of the week, the seeds should have germinated and should show a root and a shoot (the root will be covered with root hairs). At the end of the week, ask the students if their guess (hypothesis) was correct and why. This part is analyzing their data. Then have the students share their results with the class.

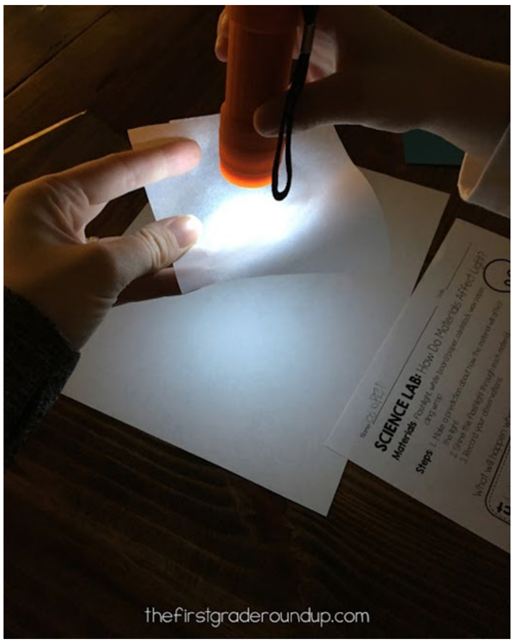
Reference: https://lor2.gadoe.org/gadoe/file/1c6c1e6f-d2de-4f7e-a699-accef337b1fe/1/Science-Kindergarten-Distance-Learning-Plan-Living-Nonliving.pdf

Source: https://lifeovercs.com/germinating-seeds-bag-science-experiment-kids/

2) <u>Transparent, Translucent and Opaque Experiment</u> In this activity, students will first hypothesize what will happen when a material is placed into the path of a beam of light, then design an experiment to find the answers.

Materials: Five of each of the following: mirror, tissue paper, plastic bag, glass jar or cup, card stock, small flashlight. Each student should have paper or a pre-printed sheet on which to record answers.

Procedure: First, define the words reflected, transparent, translucent, and opaque. Use classroom items to demonstrate each, such as the classroom wall, a window (hopefully you have one), a piece of notebook paper, and something with a reflective surface that isn't a mirror. Then ask the students to write their prediction about how much light they will see when they shine the light on the objects. Use words such as a lot, a little, none, or reflected. They can also use symbols, such as an open circle for a lot, a slightly shaded circle for a little, a dark circle for none, and an arrow for reflected.



Divide the students into five groups, give each group one of each of the items listed above, and have each group determine what they expect will happen, how they will find out, and what their results will be. Then ask them to record their answers on their sheet. This should take only a few minutes. Ideally, each student should have the opportunity to test each material for themself.

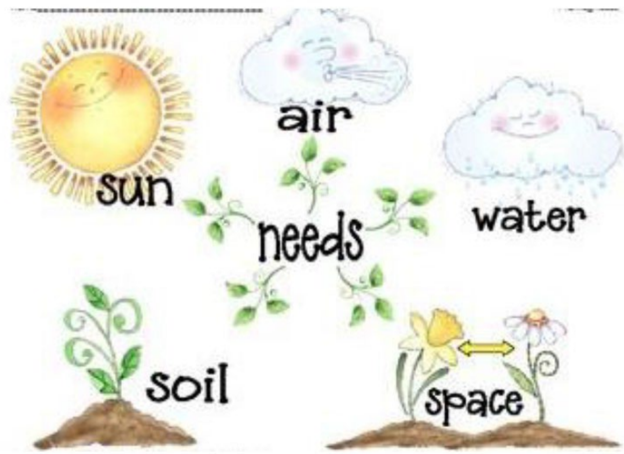
When all the groups have finished their experiments, have one person from each group tell the class what the results of just one of their experiments were, and ask if everyone agrees with the answer.

Then, have the students brainstorm about other materials they can find in the classroom or at home that are translucent, transparent, opaque, or reflective, and write these answers on the board. This last step will allow them to make conclusions and apply their new knowledge to familiar objects.

Source: The First Grade Roundup by Whitney Shaddock, 2 Engaging Light Science Experiments and Activities for First Grade. *https://thefirstgraderoundup.com/light-materials-science-experiments/*

3) Helping Plants Stay Alive (For Grade 2)

Helping Plants Stay Alive

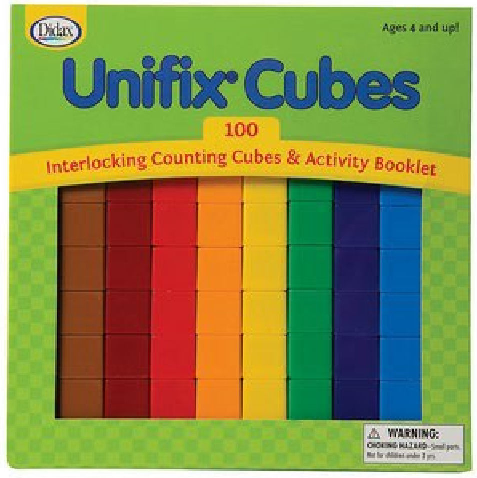


1. What could you do to help a plant stay alive?

Source: https://www.gpb.org/sites/default/files/2020-08/Science-1st-Grade-Distance-Learning-Plan-Plants-Throughout-the-Year.pdf

In this activity, students need to first learn what plants need to keep them alive. Then they will investigate what happens to plants if they receive no light or no water. If this activity is performed with only one or two students, multiple plants need to be studied before they can draw any conclusions. The plants will be observed, and height measured for a few days, and then bar graphs will be made by the students to represent growth patterns for their plants. They should then be able to use their results to draw conclusions as to whether plants need light and/or water to grow. An excellent lab is described below along with a reference to the original lab that includes full explanations and data sheets.

Materials: bag of high-quality potting soil, enough for all students to fill two 20-oz plastic cups (make sure the soil is moist and not dry before using; add water and mix in advance if necessary); several scoops; two 20-oz plastic cups per student plus six extra per class; two sunflower seeds per student plus six extra per class in case some seeds don't germinate; ice pick or similar device to punch holes in bottoms of the cups (should be done in advance by educator); black marker; water; several 1-cup measuring cups with spouts; trays to hold cups; light source (optional); 100 1-inch Unifix® cubes for measuring; 1" grid paper, three per student; three data sheets per student.



Procedure: Ask the students what plants need to grow. Ask about plants outside (trees, shrubs, flowers) and what resources they need to live. Ask the students if they think water and sunlight are needed, then ask if they want to do an experiment to find out (let them take their plants home afterwards).

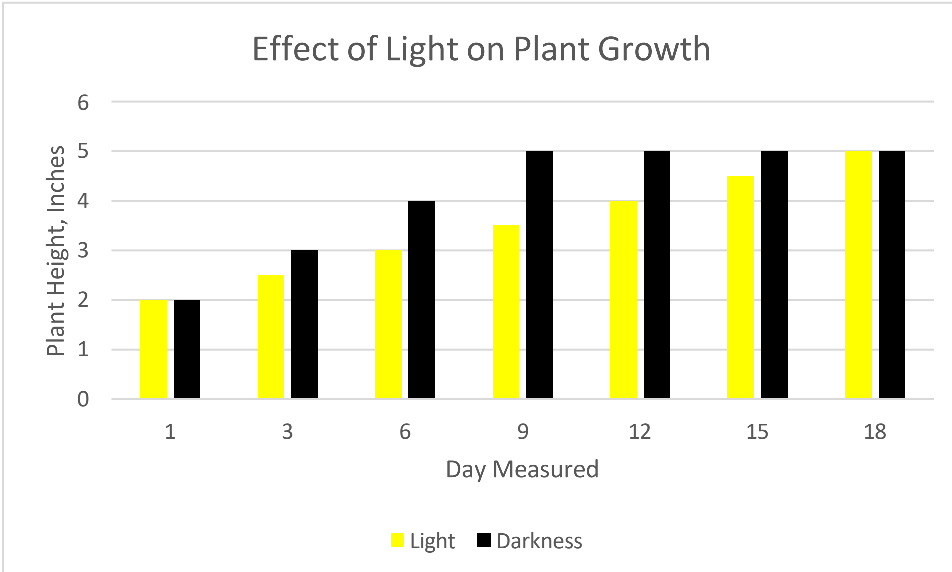
Show the students how to fill their two cups with soil (after the cups have holes punched in them). Make sure the students have left about 1" of space between the top of the soil and the top of the cup. Have the students slowly pour water on the soil in the cups until the water runs out the bottom. Give the students two sunflower seeds each and have them use their fingers to gently push the seed into the soil the distance recommended on the seed packet. (It is better if the seeds are planted too shallowly than too deeply.) Have the students gently cover the seeds with soil. Make sure the students label each cup with their names, then place all the cups in the sunlight. (If there are no windows in the classroom, the cups can be placed under a light source. A grow light will give the best results.) Keep the seeds moist but not wet, making sure the students water their cups carefully and slowly so as not to dislodge the seeds. Explain to the students that sometimes seeds don't grow, so there are extra plants that a student can use if the first ones don't grow. Once the plants appear and are about an inch high, the experiments can begin. The educator may want to mention that the first "leaves" that appear are the insides of the seed (these are called cotyledons and are false leaves). As the plant grows, the true leaves will appear.

Source: Arz, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:A_sunflower_seed_growing.jpg

Once the plants are about an inch tall, have the students measure the height of their plants with the measuring cubes and write down their data. (The educator may want to prepare a data sheet in advance to give to the students to use.) Divide the students into two groups: one that tests light and one that tests water. The group that tests water should label each cup with a water droplet for the one that will get water, and a water droplet with a line drawn through it for the one that does not get water. Likewise, the students testing for sunlight should draw a sun on the plant that will get light and a sun with a line drawn through it for the plant that will be put in a dark location (a cabinet or a closet). These plants will only be taken out every few days to measure and water but then must be put back in the dark. Have the students write down their predictions on their data sheet; this can be done by drawing pictures of what they think each plant will look like after the experiment. Be sure to put the plants that will be in darkness in a place where the temperature is not significantly different from the temperature of the location where the plants in light will be. Large differences in temperature will affect the growth rate.

Have the students take measurements once every few days until the healthy plants are about five inches tall. Have the students calculate how much each plant grew between measuring times by subtracting and have them record that information along with descriptions of differences in the appearance between their two plants and how they look different from other students' plants. Have the students explain why simply measuring the height of the plant is not a good indicator of how healthy the plant is.

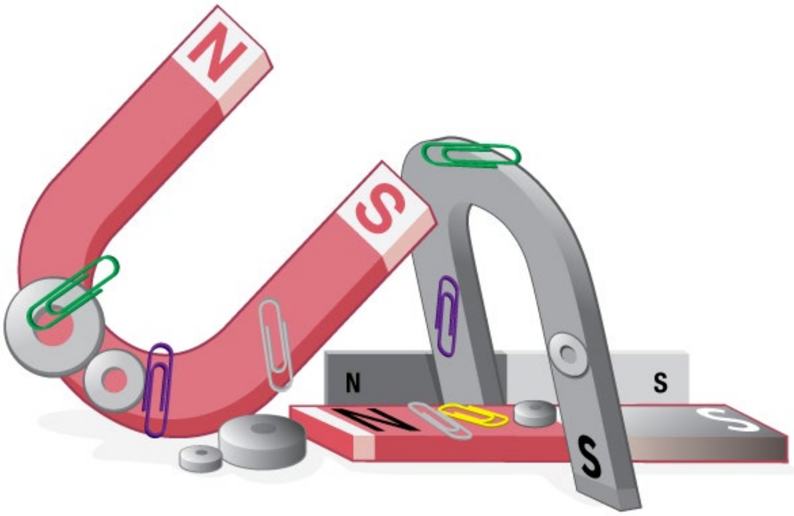
When the last data have been collected, it is time to graph it using the 1"-grid paper. Show the students how to do this and have them be consistent with their color coding. A sample graph is shown below. Then post the graphs in the classroom and discuss them.



Source: https://www.teachengineering.org/activities/view/duk_sunflower_mary_act

4) **Balanced and Unbalanced Forces. (Grade 3)** Students are asked to be able to explain how balanced and unbalanced forces will work on an object to affect its motion. In this inquiry-based lab, students will design an experiment to answer a previously written hypothesis, collect data or information, draw a conclusion, and apply what they have learned to predict outcomes of specific circumstances.

   Materials: a horseshoe magnet or bar magnet and metal marbles that are attracted to the magnet or other small objects; small toy cars, and books and cardboard to use as a ramp; a stack of playing cards or note cards; glass marbles and unsharpened pencils that can be used like cue sticks; paper or a preprinted data sheet to allow students to record their answers. The number of objects provided can be determined by the instructor. These different items can be set up at separate stations for small groups of students.



Source: OpenStax, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Openstax_college-physics_22.3_various-magnets.jpg

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Source: Killarnee, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Large_house_of_cards.jpg

Source: James Kevin McMahon, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Marbles_at_the_2016_British_and_World_Marbles_Championship.jpg

Procedure: First, be sure to explain to the students what a force is and the difference between balanced forces and unbalanced forces working on an object. The instructor may wish to ask the students about gravity and how it is a force that keeps objects on the ground.

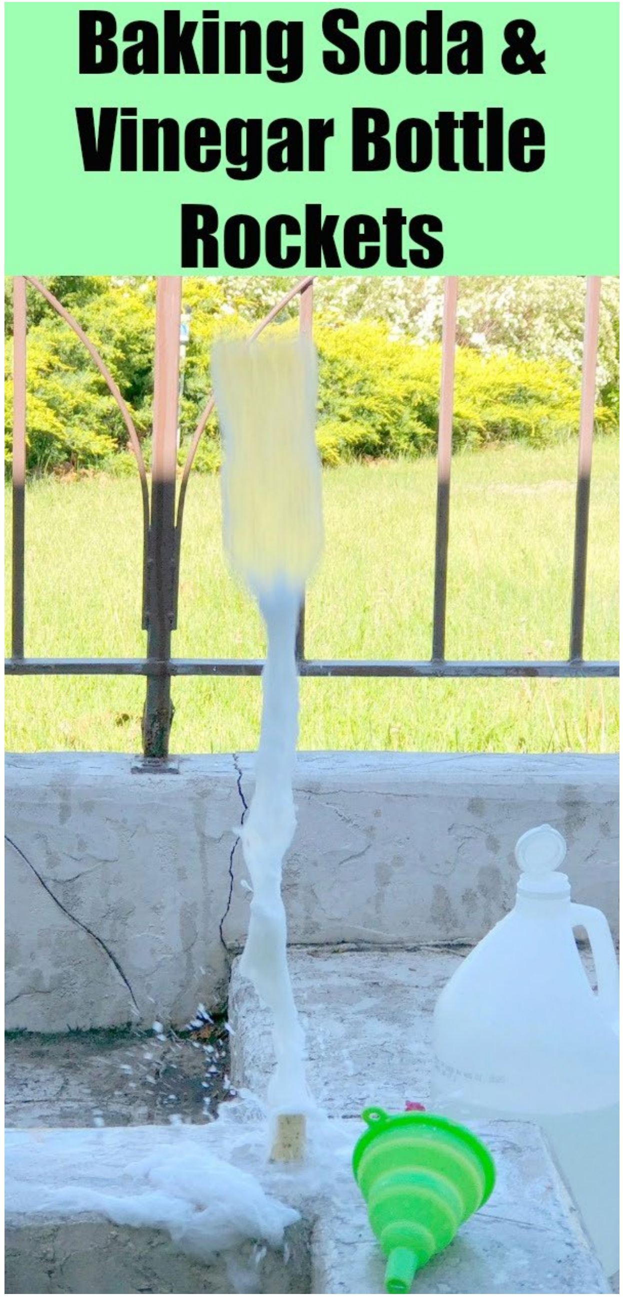
Next, the students can either be assigned to a station or can choose their own station. Try to keep the groups small if possible (no more than 4 students). Once the students are at their stations, ask them to look at the objects at the station and determine what experiment they could do to show how balanced forces and unbalanced forces may affect the motion of the object (marbles, cars, cards). Next, have them write a hypothesis that addresses what they think will happen if they create balanced forces and separately, what will happen if they create unbalanced forces. Encourage them to be more specific than simply saying "the object will move." Check to make sure they have written a hypothesis before going to the next step.

Next, allow the students to set up the objects in ways that they can find out whether their hypothesis is correct. Be sure to give them suggestions if they are having trouble designing an experiment. Remind them that forces have both strength and direction, so they need to design an experiment to see what happens when the strength of the force is changed, and another to see what happens when the direction of the force is changed.

Monitor the students to make sure they are writing down their observations and designing two experiments. They should also include on their data sheet a brief conclusion addressing both balanced forces and unbalanced forces in their experiment. When the students have finished (30 minutes or less should be adequate), have one student from each group share with the class what their experiment was, what their results were, and what their conclusions are. The representative may want to give a small demonstration of the experimental designs.

As follow-up, give the students examples of objects that have forces on them and have the students identify the balanced and unbalanced forces. Pictures of situations with which they are familiar, such as playground equipment, would be good examples.

Finally, as a fun application, go outside and have the students construct a simple bottle rocket (*Quick Bottle Rockets with Baking Soda and Vinegar, https://teachbesideme.com/quick-bottle-rockets/).* Before doing this activity, have the students predict what will happen when balanced forces are exerted, and what unbalanced forces are exerted.



5) **Are Leaves Necessary for Plant Growth? (Grade 4)** In this experiment, students must first answer the question with a hypothesis, then design an experiment to determine the answer. Afterward, they will need to apply their understanding to new situations.

Materials: Mung bean plants that have been grown by the students; light source; water; pots and potting soil; paper or pre-printed sheet on which to record data.

Procedure: Most students will say, yes, plants need leaves to grow. The big question is how to support their hypothesis.

In this experiment, the question will be asked by the instructor, and each student will need to write a hypothesis to answer the question. Each student should grow their own plant for this experiment. Seeds that germinate quickly include any kind of bean seed obtained from a garden center. Mung beans will sprout in 2 – 5 days, but other beans will work as well. (Bean seeds from the grocery store may not be viable and may not germinate.) If the classroom does not have windows, a light source will be necessary. The students should get several seeds and put them on top of the potting soil in the pot, gently cover with a small amount of extra soil, and watered. The soil should stay moist but not wet. Make sure each student labels their pot before putting it under the light source or in a window. Planting several seeds will ensure that at least one germinates. If several do germinate, pick the seedling that looks strongest and pull the others out.

Source: Pixabay. https://pixabay.com/photos/beans-leaf-food-bush-bean-5466103/

Once the plants have grown many leaves, ask the students to brainstorm about how they could determine whether the plants need the leaves to grow. The most obvious answer is to pull the leaves off of the plant and see what happens. This is a good time to introduce the concept of a control, so the students have one or more plants from which the leaves are removed, and others with all their leaves to allow the students to compare. Divide the students into groups of four and ask them to design an experiment to test their hypothesis. An interesting variation would be to have students remove some, not all, of the leaves on the experimental plant and determine how many must the plant lose before the plant growth is affected.

On the data sheets, ask students to record what they see. One way to determine growth would be to measure the height of both the control and experimental plants to see if there is a difference. Determine how long the experiment should last before the students write their conclusions. In their conclusion, they should go back and address their hypothesis and state whether it was supported and why.

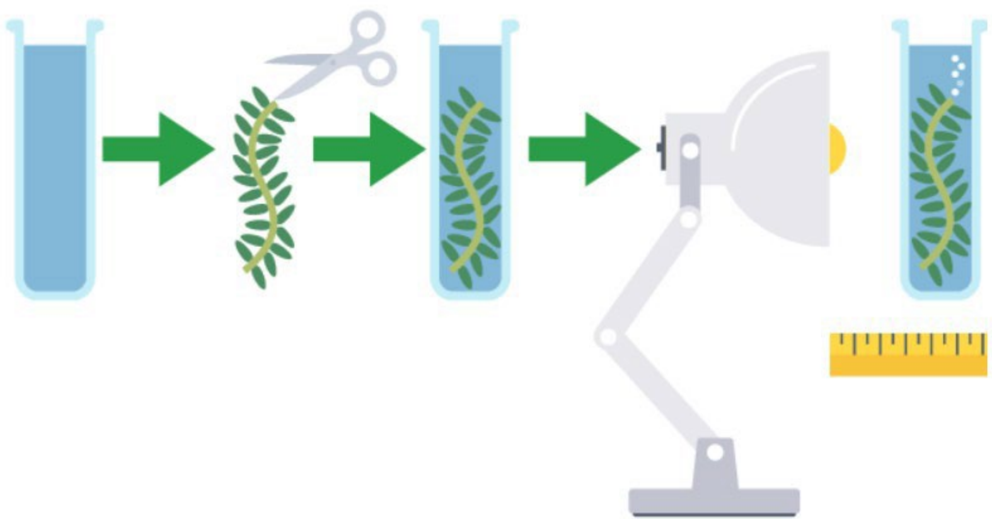
An extension to this lab would be to show the students pictures of different plants that do not have leaves and ask them how these plants survive without them. Examples could include horsetails (a very ancient species of plant) and different types of cacti. The instructor should ask what all these plants have in common (color), and how that color might be critical to plant growth.

6) **What do plants need to stay alive? (For Grade 5)** At grades 3-5, students should know that plants need sunlight, air and water to stay alive. They should be taught that there are gases in the air that plants must have, which can be accomplished by letting them watch the CO_2 Coalition's Learning Center video, Gases in the Air. Photosynthesis is the chemical process by which plants take CO_2 from the air and make it into plant food using sunlight and water. Even though the students don't need to know how the process works at this age, they should know that plants take in CO_2 and release oxygen. This process can be easily demonstrated using the following experiment.

   Materials: Elodea (an aquarium plant that can be found in stores selling aquarium supplies) or another aquatic plant with large leaves (please destroy these plants when finished with the experiment or keep them in an aquarium. They are extremely invasive and can destroy aquatic ecosystems if released into a body of water); baking soda; test tube; test tube holder or 16-oz clear plastic cup; a light source (LED lights work best because they do not give off enough heat to affect the temperature of the water); spring water.

   Procedure: Show the "Gases in the Air" video to the student(s) and ask the student questions, such as what gas in the air do plants need, where does oxygen come from, what part of the plant takes in carbon dioxide and gives off oxygen. Ask the student how it might be possible to see a gas being given off by a plant. When plants are in the presence of light, they take in carbon dioxide through small openings in their leaves called stomata (stomate is singular). The stomata also release oxygen into the air. If a leaf is put under water, the gas bubbles of oxygen on the leaves can be easily seen to form.

First, make a weak baking soda solution by dissolving 1/8 teaspoon in 1 1/3 cups of water. Put this solution in the test tube. (The test tube could be held upright using a test tube holder, or by simply resting it in a 16-oz clear plastic cup.) The purpose of the baking soda is to increase the amount of carbon dioxide in the water since baking soda will release CO_2 in solution. Next, put a strand of Elodea into the water and put the cup with the plant 10 cm in front of a plant light. Have the student record observations: How far away is the plant from the light? What time did the first bubble appear? After 1 minute, how many bubbles have formed? Have the student make observations for 5 minutes. This data can be plotted on as a line graph using Excel or a sheet of graph paper.



Source: https://www.bbc.co.uk/bitesize/guides/z9pjrwx/revision/7

This experimental setup will be the control for the next experiment, which investigates the effect of light intensity on the rate of photosynthesis. Ask the student what will happen if the light is moved further away. This prediction is the hypothesis of the experiment. Ask the student how the light intensity could be changed if the light is not changed. The answer is to move the light away from the plant. The constants in this experiment are the light source, the plant, the water, the test tube, the test tube holder or plastic cup, the time interval at which measurements are taken, and the temperature. The independent variable is the distance between the light source and the plant; the dependent variable is the number of bubbles produced after 5 minutes at that distance.

Let the student determine what distances the plant should be from the light source; a bit of trial and error will allow the student to figure out the best setup. Have the student try several different increasing distances and collect data from each run. Ideally, if time allows, the student should repeat the experiment multiple times by using a fresh sample of plant and fresh solution with each run, leaving all the other factors the same. The data points taken at each distance may be averaged together and the average should be plotted on a graph. The independent variable, distance to light source, should be plotted on the horizontal or x-axis, and the dependent variable, the number of bubbles, should be plotted on the vertical or y-axis. Then the student should be able to see if the hypothesis is supported or can be rejected. The data, an explanation of the experiment, and a discussion of the results (conclusion) should be presented in a way that the educator determines.

7) **Demonstration of Release of Oxygen during Photosynthesis (For Grades 6-8 or older):** An aquatic plant is used to demonstrate the formation of a gas (oxygen) during photosynthesis. Then, baking soda will be added to the water in varying amounts to see if the amount of carbon dioxide in the water will change the rate of photosynthesis.

Materials: Either spring water, pond water, or water from the store where the plant was purchased; hydrilla or elodea (please destroy these plants when finished with the experiment or keep them in an aquarium. Hydrilla is extremely invasive and can destroy aquatic ecosystems if released into a body of water); glass jar, drinking glass or beaker; glass or clear plastic funnel; test tube or 25-mL clear glass graduated cylinder (can be purchased on Amazon); baking soda; bright light source; timer.

Procedure: *Start by asking the students questions about what photosynthesis is.* By now, they should be able to discuss that photosynthesis is a chemical process that occurs within the leaves of plants, and that plants need carbon dioxide, water, and sunlight to perform photosynthesis. Then ask the students what the products of photosynthesis are; at this age they should know that oxygen and plant food, or glucose, are the products. If they have forgotten, let them watch the short video Where the Gases Come From on the CO_2 Learning Center website (CO2LearningCenter.com).

Once it has been established that oxygen is given off by plants, ask the students to guess how much time it would take for the plant to fill the entire test tube with gas. Write the most popular answers on the board and let these guesses be their hypotheses. After the lab, revisit the hypotheses and see which one best predicted the actual results.

The first experimental setup will be the control, which is used to determine a rate of photosynthesis to which the experimental groups will be compared. It will also be used for comparison after a new variable is introduced.

Experimental setup: Fill the beaker with water that does not contain baking soda and place the plant at the bottom of the beaker. Completely cover the plant with the funnel as shown in the diagram below. Fill a test tube or graduated cylinder with the same water and invert it over the end of the funnel so that there are no air bubbles present in the test tube. Put the beaker next to a bright light source. (Since the sun's angle and intensity vary with time, using a light source will provide a constant light over a long period of time.) Measure the time it takes to fill the test tube with gas (oxygen); this can be used to calculate the rate of photosynthesis. It might be helpful if marks are drawn at regular intervals onto the test tube with a permanent marker or to use a small, graduated cylinder instead of a test tube.

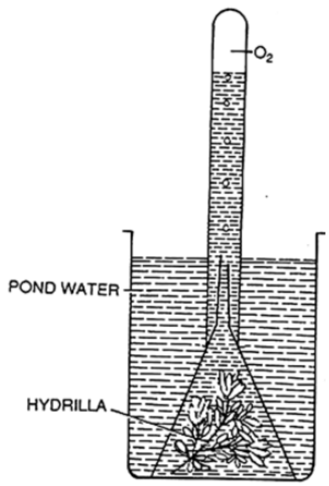


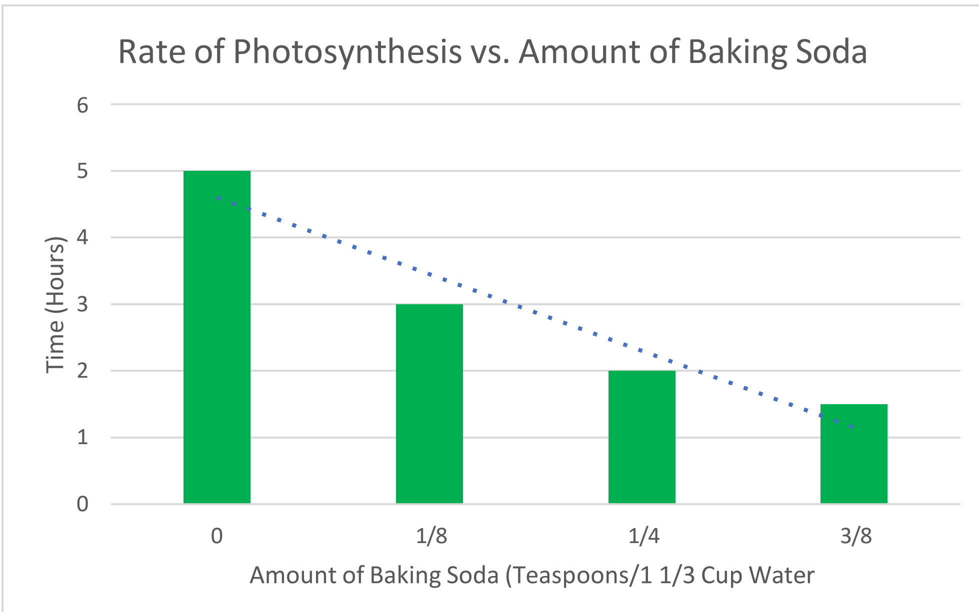
Fig. 5.22. Liberation of oxygen in photosynthesis. Demonstration of the phenomenon.

Source: *https://www.yourarticlelibrary.com/experiments/photosynthesis-experiments/top-10-experiments-on-photosynthesis-with-diagram-botany/90902*

To test for oxygen in the test tube, get a wooden splint (or a Popsicle stick), ignite it, let it burn for a few seconds, then blow it out and insert it into the still upside-down test tube. The splint will either glow very brightly or burst into flame in the presence of oxygen. Repeat this experiment, if possible, three times to make sure you get the same answer all three times.

Introducing the independent variable: The student will determine if carbon dioxide from the baking soda impacts the rate of photosynthesis instead of light intensity. Start by dissolving 1/8 teaspoon of baking soda in 1 1/3 cups of water. Allow the student to determine three more concentrations of baking soda and have the student write a hypothesis on a sheet of paper. Three possible hypotheses are 1) more baking soda increases the rate of photosynthesis; 2) more baking soda reduces the rate of photosynthesis; and 3) there will be no effect on the rate of photosynthesis. The independent variable is the amount of baking soda, the dependent variable is the rate of photosynthesis, and the constants are the distance of the light source to the setup, the temperature, the type of water, the type of plant, the test tube or graduated cylinder, and every other part of the experimental setup that was used before.

Have the student set up three of the same arrangements as before with varying amounts of baking soda. (These can be run individually or simultaneously.) Measure the relative rates of photosynthesis by measuring how long each test tube takes to reach an equal amount of oxygen as was present in the control test tube. These results should be recorded in a data table and the results should be graphed. An example is given below, where each bar represents each experiment.



The student should use the experimental results to determine whether to support or reject the hypothesis. In the example shown in the graph above, both the second and third hypotheses can be rejected.

The student should present the results of the experiment, along with a discussion of background information and experimental design, in a way that the educator chooses.

Formative and Summative Questions

1) List the seven steps of the scientific method.
2) Explain how the scientific method could be used by a mechanic trying to diagnose the problem with a car.
3) What are two characteristics of a good scientist?
4) What is the goal of using the scientific method?
5) Some data is good data when it comes to finding the answer to a question or problem. What are some examples of good data? What are some examples of bad data?

6) Some people only look for data that supports their hypothesis when trying to find the answer to a question. Explain how this prejudice could lead the person to the wrong conclusion.
7) There are plenty of examples in history where a paradigm shift has occurred. A paradigm shift occurs when an accepted scientific explanation is proved to be false. One famous example is that of Galileo, who discovered that the planets revolved around the sun, which at the time was opposite of the accepted explanation for why the sun moved across the sky. Research to find two other examples of accepted scientific explanations that were proven to be false.
8) Why is data more important than opinion when using the scientific method?

Next Generation Science Standards (NGSS) Learning Objectives

The Next Generation Science Standards (NGSS) define three distinct and equally important dimensions to learning science. These dimensions are combined to form each standard—or performance expectation—and each dimension works with the other two to help students build a cohesive understanding of science over time. These three dimensions include cross-cutting concepts, science and engineering practices, and disciplinary core ideas. These dimensions are then adjusted to each age and grade level. The purpose of this approach is to integrate traditional science content with engineering through a practice or disciplinary core idea.

Within the dimension of science and engineering practices, there are several practices that apply to the scientific method. These practices include asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, engaging in arguments from evidence, and obtaining, evaluating, and communicating information. The only cross-cutting concept that applies to the scientific method is cause and effect.

There are eight lessons in middle school, nine lessons in grades 3-5, and ten lessons in grades K-2 that include steps associated with the scientific method. All of these lessons, however, include only one step in the scientific method, although that step could be different depending on the lesson. None of the lessons include all the steps, even for the middle school grades. This data includes all science categories or disciplinary core ideas.

Specific standards have been chosen for this section that include at least one step of the scientific method and therefore can be used to justify the use of this book in a public classroom. Please note that many of these standards ask the students to support a statement as opposed to starting with a question and answering it with data collected by the student. The best analogy is the difference between a crime investigator deciding in advance who the perpetrator is and then searching for evidence to support his conclusion as opposed to looking at all the evidence before determining who the most likely suspect is.

The standards here are written exactly as they are written in the NGSS.

K-LS1-1 From Molecules to Organisms: Structures and Processes. Students who demonstrate understanding can:

K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive. [Clarification Statement: Examples of patterns could include that animals need to take in food but plants do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and, that all living things need water.] This standard includes the following Disciplinary Core Ideas:

LS1.C: Organization for Matter and Energy Flow in Organisms

- All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.

1-PS4-3 Waves and Their Applications in Technologies for Information Transfer. Students who demonstrate understanding can:

1-PS4-3. Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light. [Clarification Statement: Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).] This standard includes the following Disciplinary Core Ideas:

PS4.B: Electromagnetic Radiation

- Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.)

2-LS2-1 Ecosystems: Interactions, Energy, and Dynamics. Students who demonstrate understanding can:

2-LS2-1. Plan and conduct an investigation to determine if plants need sunlight and water to grow. [Assessment Boundary: Assessment is limited to testing one variable at a time.] This standard includes the following Disciplinary Core Ideas:

LS2.A: Interdependent Relationships in Ecosystem

- Plants depend on water and light to grow.

3-PS2-1 Motion and Stability: Forces and Interactions. Students who demonstrate understanding can:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.] This standard includes the following Disciplinary Core Ideas:

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)

PS2.B: Types of Interactions

- Objects in contact exert forces on each other.

4-LS1-1 From Molecules to Organisms: Structures and Processes. Students who demonstrate understanding can:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin.] [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.] This standard includes the following Disciplinary Core Ideas:

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

5-LS1-1 From Molecules to Organisms: Structures and Processes. Students who demonstrate understanding can:

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.] This standard includes the following Disciplinary Core Ideas:

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants acquire their material for growth chiefly from air and water.

MS-LS1-6 From Molecules to Organisms: Structures and Processes. Students who demonstrate understanding can:

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. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.] This standard includes the following Disciplinary Core Ideas:

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary)

Source: https://www.nextgenscience.org

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What is the CO_2 Coalition?

The CO_2 Coalition was established in 2015 as a 501(c)(3) for the purpose of educating thought leaders, policy makers and the public about the important contribution made by carbon dioxide to our lives and the economy.

The CO_2 Coalition is a group of the top scientists, engineers and energy experts who study and report on the important contribution made by carbon dioxide to our lives and the economy.

Learn more at CO2Coalition.org and CO2LearningCenter.com.