1 Effects of the Environment on Plant Growth

Unit Essential Question

How do the environment and genetics affect who we are and how we are similar or different?

Introduction

There are variations in all living organisms. Some variations are a result of genetic information that the organism received from its parents. Other variations are a result of different environments that an organism lives in. In this task, students will observe and gather evidence about how genetic and environmental factors influence the growth of plants. In part I, students will examine a variety of beans to identify some of the characteristics of beans, compare and contrast the characteristics of different types of beans, and explain why they think some characteristics are the same and some are different. In part II, students will brainstorm ways the environment might cause variation in the growth of plants. Students will select a specific environmental factor and design a controlled investigation to determine what effect the environmental factor has on plant growth. Students may gather their data periodically through task 2 and reflect on their data after task 2.

Objectives

Students will be able to

Content

- Determine how different environmental conditions affect plant growth rate.

Science and Engineering Practices

- Plan and conduct an experiment about environmental effects on plant growth.
- Use data to construct an explanation about how the environment and genetics influence plant growth.

Equity and Groupwork

- Discuss and plan procedures.

Language

- Write a lab report.

Academic Vocabulary

- control group
- environmental conditions
- experiment
- experimental group
- organism
- prediction
- standard factor (fair test)
- variable

Language of Instruction

- justify
- initially

Timing

This task can be completed in 14–16 class periods (based on 45-minute periods).

- Part I • Variation of Beans (1 class period)
- Part II • Design an Experiment to Analyze How the Environment Affects Physical Traits of a Plant (12–14 class periods)
  - 1 day: Brainstorm the experiment.
  - 1 day: Set up the experiment. (If short on time, this can be done at the end of the previous day.)
  - 1 day: Discuss and set up the data table.
  - 1 day: Write the experiment in science notebook. (If short on time, this can be done on the previous day.)
  - 5–7 days: Conduct experiment and gather data. (The timing depends on whether a weekend is included and whether writing in the science notebook and discussing the data table are part of these days. This part of the task will not take the whole period, but rather a few minutes at the beginning or end of class.)
  - 1 day: Make a graph.
  - 1 day: Analyze and make conclusions. (If short on time, add this to the previous day and have students complete the remainder for homework.)
  - 1 day: Share data, analysis, and conclusions.
- Part III • Connect to the Culminating Project and Assessment (1 class period)

Student Materials

per group

Part I:

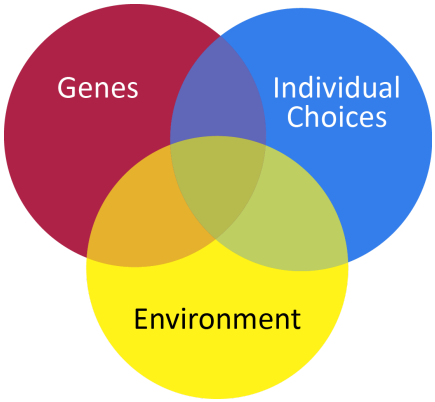
- Bag of mixed beans
- Metric ruler

Part II:

- Kidney beans (approximately 6 per group—3 for the experimental group and 3 for the control group)
- Paper towels (used to make "growth chambers")
- Plastic plates (to put growth chambers on) or plastic bags (to store growth chambers in)
- Permanent pens (to label growth chambers)
- Possible environmental factors:
  - Vinegar (This a weak acid.)
  - Detergents/soaps (These are bases.)
  - Fertilizer (This adds minerals.)
  - Heat (Use a heat lamp, but cover beans up so light is not a factor.)
  - Cold (Put beans in a refrigerator.)
  - Dark (Put beans in a paper towel.)
  - Light (Don't cover beans in a paper towel, but make sure there is lots of water under under the beans for germination. Perhaps put beans in a container with a half inch of water.)
  - Wind (Use a fan.)
- Small cups or beakers (to measure the amount of water the beans are given every day)
- Ruler (to measure bean growth; have both metric and English standard rulers available, since students will decide what units they want to use)
- Graph paper
- Large poster paper (to draw and display each group's graph of data)

Background Knowledge

The nature versus nurture issue has been debated since DNA was discovered as the blueprint of all proteins, and thus the blueprint for the structure of life. Nature is the DNA component, or the inherited traits, and nurture is the environmental impact on traits, or the acquired traits. At some points in history, the predominant theory was that DNA is the dominant force that determines the looks and personality of an individual. At other times, the predominant theory was that the environment is the dominant force that determines the looks and personality of an individual. Today, most scientists believe that living organisms are not completely predisposed at birth by DNA. Although DNA determines the general characteristics of an organism, the organism's structures and personality may be influenced by life experiences and the environment they live in. Most scientists now agree that there is no fine line between nature and nurture. Instead, nature and nurture both influence the traits of an organism.



One new field of study that has contributed to the fuzzy line between nature and nurture's impact on living organisms is epigenetics. Epigenetics is the study of how cellular and structural trait variations may be caused by external or environmental factors that can "switch" genes on and off. In the case of epigenetics, there is not a genetic change or mutation in the DNA. Instead, genes are blocked by a methyl group (a process called *methylation*), or undergo a histone modification. What this means is that our environment can alter the expression of our genes, causing altered phenotypes, and these alterations can be passed on to future generations. For example, the two mice below are genetically identical, but the color and obesity genes for the mouse on the right have been methylated, and thus these genes are not being expressed. In the mouse on the left, the methyl group on the color and obesity genes has been removed, and now the mouse is an agouti color and is not obese. The mouse example shows that even if the genes are all the same, the physical structures or phenotypes can be different due to blocked gene expression.

For the purpose of this task, students only need to know that in addition to genetics, the environment can cause changes in the phenotype, or the look or growth patterns of an organism.

Introduction

1. Read the introduction in the Student Edition together as a class, allowing students to reflect back on the previous task and connect it to the task that lies ahead.
2. Have students answer the prior knowledge question as a warm-up using a think-pair-share format so every student is able to access their own prior knowledge about plant and animal growth. Students should build off their basic experience with gardening, owning pets, taking care of younger siblings, etc. Ask facilitating questions to help students access these experiences.

   Possible responses could include discussions of how plants with more water or sunlight grow taller than others; babies with less nutritious food may not grow as big or strong; dogs that are not bathed regularly could get dandruff or start losing hair.

Part I • Variation of Beans

1. Place students in their project groups. Designate student roles and review the norms.
2. Set up a bowl of mixed beans at each table.
3. Ask students to examine the bowl of beans at their table and generate a list of various bean characteristics that could be compared from bean to bean. Possible comparable bean characteristics are:
   - Length
   - Width
   - Number of stripes
   - Pattern of stripes
   - Color
   - Fat or skinny in depth
   - Texture
4. Discuss with the whole class the characteristics, or **traits**, that the beans have.
5. Have each group identify several characteristics that they want to compare. Then have them compare four different beans and fill in the table in the Student Edition. When they have finished, tell them to return the beans to the bowl.
6. Now ask students to find the four beans they compared by analyzing the traits of all the beans and matching four beans to the traits they recorded.
7. Have students use evidence and reasoning to support the following claim: Beans have many different traits.
   - Students may struggle with determining a scientific concept to use in their reasoning. Ask students to think back to the slides they viewed in the previous task, and the terms they learned. Possible facilitating question: You learned that many traits are inherited. What does that mean and how does it work?

LANGUAGE SUPPORT: CLAIM, EVIDENCE, REASONING SENTENCE FRAMES

Provide the following sentence stems as needed.

- Evidence: “Some beans have _____, but other beans have _____.”
- Reasoning: “The beans could look different because _____.”

8. Have students share their bean comparisons and claim, evidence, reasoning statements. Use a share-pair, or hold a full-class discussion by calling on students to contribute examples of evidence and reasoning from their own claim, evidence, and reasoning responses.

Sample Explanation

Claim Beans have many different traits.
Evidence Use evidence from your observations to support the claim. *Students should use the different traits (characteristics) they identified in their bean comparison chart. For example: Some beans have stripes, but other beans are a solid brown color. Some beans are 15 mm long, but other beans are only about 4mm long.*
Reasoning Use a scientific concept to explain why your evidence supports the claim. *Due to the different genes in a bean, the beans look different.* *The beans are different because they came from different seeds and from different "parent" beans.* *The beans are different because they don't all inherit the same genes.* *It depends on their "parent's" genes.*

Part II • Design an Experiment to Analyze How the Environment Affects Physical Traits of a Plant

When you look at variation between types of beans, you are looking at **genetic** variation. For this task, students will investigate ways that the environment might cause variation in bean growth. Note that his task exemplifies the crosscutting concept highlighted in this unit: **cause and effect**.

A. Experimental Question

1. Place students in their project groups. Designate student roles and review the norms.

LANGUAGE SUPPORT STRATEGIES

Ensure that ELLs are in groups with students of higher proficiency, and encourage the group to engage all group members in their roles.

2. Review the experimental question provided in Part A of the Student Edition.

B. Brainstorm Your Experimental Design

3. Begin the brainstorming process in Part B. Ask students to brainstorm in teams ways that the environment might be responsible for variations in beans. In this exercise, students should be activating their own prior knowledge and experiences as they did for the question in the introduction. Refer any students who are "stuck" back to the introductory question.
4. Discuss all groups' ideas with the class. Display the list of ideas for the class to see.

   Some possible ideas are:
   - *Amount of water*
   - *Amount of wind*
   - *Type of soil*
   - *Amount of nutrients in the soil*
   - *Amount of sunlight*
   - *Temperature*
   - *Watered with acid (acid rain) or base (soap) solution*
   - *Presence of toxins*
5. **Model** the process that students will follow in designing their experiment. Then let them work in small groups to design their experiment. As students work, move from group to group to monitor progress and ask questions to guide groups who need direction or need more specifics in their thoughts and ideas.

Design Step	Helpful Hints
Variable	**Group decision:** Student groups can choose one of the environmental conditions they brainstormed previously, or decide on a different environmental condition (with teacher permission). This condition should be general—for example, "amount of water" or "with or without toxins." Review each group's choice and initial when approved.
Control	**Group decision:** The control setup will not use the environmental condition (variable). For example, if the variable is water, the experimental group will have water and the control will not.

Design Step	Helpful Hints
Measurements	**Class decisions: Have the class decide on and use the same units so that all the data can be compared.** It is recommended that all students use metrics, millimeters or centimeters. Review the meaning of each mark on the ruler. Average the bean data each day. As beans start to grow, add the measurement of the root and the stem together for the final measurement. See sample data tables at the end of these instructions. Ask students to draw their beans and take some observation notes each day too.
Experiment	Students will use the same basic setup design, as follows. 1. Students' beans will go into a "growth chamber." This growth chamber will be a paper towel that has been folded into fourths with the beans in between the folds. Demonstrate the growth chamber for students—for example, use a 12" x 12" paper towel and fold it into a 3" x 3" square. Emphasize that students should not fold the paper towel too many times or fold it too tightly because the beans need **oxygen** to grow. Students will have one growth chamber for their experiment beans and one for their their control beans. 2. Students will store the growth chambers either on a plastic plate or in a plastic bag (they should not seal the bag because plants need oxygen). 3. Students should label their two growth chambers with their names, with either "experimental" or "control," and, for the experimental setup, with the variable the beans are exposed to. 4. After they have placed the beans in the growth chamber, students will expose the paper towel in the experimental setup to their chosen variable. 5. Students will create a data table based on their experiment and record the table in their science notebook. 6. **Important point for success:** Students should make sure the paper towels are very wet every day. The beans need to get completely wet to germinate. The beans will need approximately 10 ml of water every day to stay wet. However, the beans should not sit in a pool of water, because they will drown and rot without oxygen present. 7. Each day, students will take the beans out of the paper towel and measure them—both the root and the stem. They will record their data in their data table. 8. When they have finished recording data, students will return beans to the growth chamber. They will water the beans every day, or enough to keep the beans damp. (Give same amount of fluid to each bean group.)
Draw the Experiment and Control Design	Students will draw both the experimental setup and the control setup. Remind students to label their drawing and include amounts of materials. For example, they should include the water (or experimental substance) they will add to the beans every day. Review and initial students' drawing to make sure their setup is viable.
Standard Factors	The standard factors will be a list of everything that will be the same in the experimental setup and the control setup. For example, if students are testing whether acid affects bean growth, they would put the same amount of acid solution on the experimental beans as the amount of water on the control beans. Another example is that the beans in both setups will be given the same amount of time to grow.
Prediction	Students should not only give a prediction for what they think will happen, but also why they think it will happen. This emphasizes the crosscutting concept of cause and effect.

6. When the small groups have designed their experiments, review each experiment, and then let students get started setting up their experiment and control.
    - It is important that students plant their beans as soon as they have designed their experiment, since it takes seven days to see the effects of different variables. Students can work on their formal experiment write-up in their science notebook after they have set up their experiment.
    - Remind students to label each growth chamber with their names and the variable the beans are exposed to.

C. Record Your Experimental Design

7. Have students write a formal description in their science notebook of their experiment, following the guidelines in the Student Edition.

   Students will need to determine a structure for the data table that they will use to record their results. Below is a sample data table. Discuss data table options with the class and then give small groups time to design a data table that will work for their experiment. Have students draw their data table in their science notebook with their complete experimental design write-up.

   - Step 7 can be done the day after students set up their experiment and on the first day of growth measurement (although on the first day of measurement, students should expect that their bean will have grown in size, but that no roots or stems can be seen yet).

Sample data table:

Plant Growth (mm) and Observations		
DAY	*Experimental Condition*	*Control Condition*
1		
2		
3		
4		
5		
6		
7		

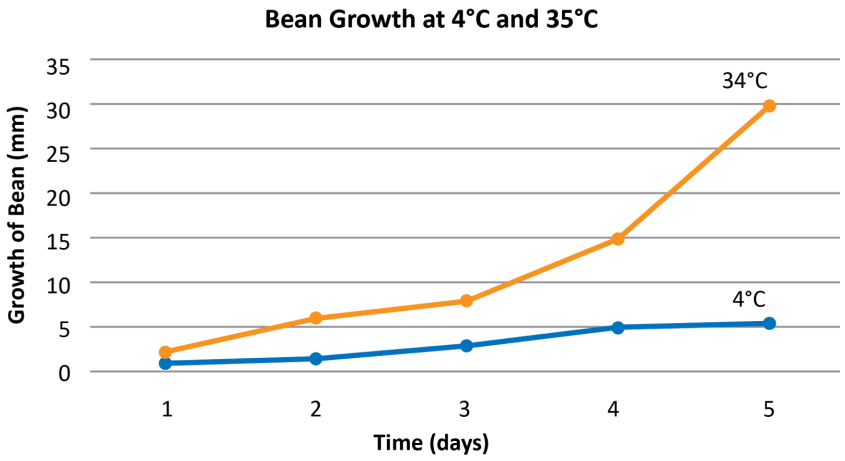
D. Conduct Your Experiment

8. Have students measure beans, draw beans, and make observation notes every day for seven days, using the following guidelines.
    a. Take the bean plants out of the paper towels.
    b. Measure each bean plant.
    c. Average the measurements in the experimental group and average the measurements in the control group.
    d. Record these averages in your data table, along with other observations and drawings.
    e. Return the beans to the growth chamber.
9. Students should water the(or use othappropriate fluid) every day. Tell them to use enough fluid to keep the beans damp, and give the same amount of fluid to each bean plant.

Important point for success: Students should make sure the paper towels are very wet every day. The beans need to get completely wet to germinate. The beans will need approximately 10 ml of water every day to stay wet. However, the beans should not sit in a pool of water, because they will drown and rot without oxygen present.

E. Graph Your Data

10. After the beans have grown for seven days, the data is ready to graph. Review graphing procedures with students. If you have access to large poster paper, have each group make a large graph to post around the room for the review discussion about their data analysis and conclusion. A sample graph is provided below.



- Another option is to have students use an online graphing tool to graph and print their data, such as https://nces.ed.gov/nceskids/createagraph/. These graphs can then be pasted in students' science notebooks.

F. Analyze Your Data and Make Conclusions

11. Give time for students to discuss the two questions in the Student Edition.
12. Have students fill in the Claim, Evidence, Reasoning table in the Student Edition. Discuss students' claim, evidence, and reasoning ideas as a class. A sample table is provided below.
    - Students may have trouble coming up with scientific concepts to use for their reasoning. One option is to brainstorm some general ideas together, using facilitating questions such as: "How were your kidney beans similar before you started your experiment? Why were they similar? How were they different after your experiment? Why do you think that happened?"

LANGUAGE SUPPORT: SENTENCE FRAMES

Provide sentence stems for each part of the Claim, Evidence, and Reasoning table.

- Claim: "When plants are grown with _____, the result is _____." OR "Plants grow better with _____ than with _____."
- Evidence: "Plants with _____ grew to ____ mm, while plants with _____ grew to ____ mm." OR "Plants with _____ grew every day, while plants with _____ took many days to start growing."
- Reasoning: "These results were because _____." OR "All kidney beans _____." OR "The differences we saw were because _____."

Claim ● When plants are grown with periodic watering, the results are better. ● Plants grow better when watered every other day than whenwatered weekly.
Evidence ● Plants with water every other day grew to 15 cm over seven days, while plants with water once a week grew only 1 cm over seven days. ● Plants with water every other day grewon average 2.1 cm per day, while plants with water once a week grew only .1 cm per day. ● Plants with water grew every day, while plants with water once a week took five days to start growing.
Reasoning The environment affected the growth of plants. Both plants we tried to grow are kidney beans, so all the beans have similar DNA. What caused the kidney beans to grow at different rates was the environmental situation, or the type of liquid they were grown with. The frequent water environment was best for bean growth.

G. Communicate Your Findings

13. Let students share out their data, analysis, and conclusions. Remind students to:
    - Describe their experiment.
    - Describe their data.
    - Share patterns they saw.
    - Share their prediction and how their prediction compared to the actual results. For metacognition purposes, emphasize that this is a time for students to reconsider and revise their ideas based on data.
14. Summarize the purpose of this task: The environment does have an effect on the traits of plants of the same species.

15. Have students discuss this question:

    Do you think the different traits that the plants have due to the environmental differences will be seen in the offspring (beans) of the plants? For example, if plants did not grow very much in the cold, will the baby plants from those plants be smaller too? (In essence, will the DNA change due to environmental differences?)

    Typically, the DNA does not change due to the environment.

    Following is additional information that sixth grade students do not need to know, but that may come up during the discussion. There are two ways that the environment can change the DNA of organisms. First, genetic mutations (change in nucleotide sequences) can be caused by some environmental conditions, such as toxins, UV light, and radiation. Genetic mutations actually change the DNA and cause different traits to be expressed, many times causing tumors, cancers, and death. Second, it has recently been discovered that the environment can cause genes to be turned on and off (by adding and taking away methyl groups on the DNA), and those "on and off" genes will be passed down to future generations. This is a new field of study called epigenetics.

16. At the end of the task, ask students to reflect on what they learned over the course of this task by answering the following question from their Student Edition: At the beginning of this task, you were asked if you thought environment could have an effect on organisms' similarities and differences. Look back at your response. Do you still agree with what you initially wrote? How could you add to or change your answer after what you have learned from this task?

    There is no right answer. Encourage students to look back at the prior knowledge question from the start of the task. They should not change their initial answer, but rather use this reflection to modify their original idea and add evidence they have collected over the course of this task.

Part III • Connect to the Culminating Project and Assessment

1. Have students independently complete the task 1 section of the Individual Project Organizer in class.
2. Collect the Individual Project Organizers and assess using these criteria:
    - The "Carrying Out Investigations," "Analyzing and Interpreting Data," and "Constructing Explanations and Designing Solutions" rows of the Science and Engineering Practices Rubric
    - A criterion of your choice
3. Return the Individual Project Organizers. Give students time to make revisions based on one of these two options.
    - Have students make changes to their Individual Project Organizer according to your comments. (This could be done for homework, depending upon students' needs and/or class scheduling.)
    - Ask students to exchange their Individual Project Organizer with a partner, and give partners 5 minutes to provide written feedback. Then allow students time to make changes to their work according to the feedback.