Same and Different - Exploring Biological Variation in School Gardens

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Introduction:

One of the most important ideas in Biology is that individual organisms differ from each other, but that this variation has recognizable patterns. To be able to study living things, scientists must be able to recognize and name groups of organisms that are similar to each other (e.g. the same species), and recognize when individuals differ from a group (e.g. when pollution or disease change the way organisms look). Similarly, to be able to grow crops farmers and gardeners need to be able to recognize crops versus weeds, and need to be able to recognize when individual plants differ from their group, for example noticing that some plants have yellow leaves suggesting too few nutrients in the soil. This series of lessons is designed to help third grade students learn to recognize and describe variation among organisms, to use evidence to assign organisms to meaningful groups, and to understand that variation among organisms comes both from genetics (inheritance) and the environment.

It is increasingly common for schools to have on-site gardens. These gardens are most commonly used to grow vegetables and support learning about nutrition and the basics of plant growth, but there is great potential for these gardens to also be used to support learning in other areas of science. This series of lessons takes advantage of school gardens (although a garden is not required) to help students connect learning about sources of biological variation with learning about food plants and how to grow them.

How these lessons intersect with the Next Generation Science Standards and Florida science standards:

These lessons were designed to address the Next Generation Disciplinary Life Sciences Core Idea (DIC) LS3: Inheritance and Variation of Traits. This is the idea that "*Different organisms vary in how they look and function because they have different inherited information. The environment also affects the traits that an organism develops."* The lessons focus on preparing students to meet two specific Performance Expectations (PE):

- *3-LS3-1: Analyze and Interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.*
- *3-LS3-2: Use evidence to support the explanation that traits can be influenced by the environment.*

These lessons focus on the Life Sciences Disciplinary Core Idea LS3: Inheritance and Variation of Traits, but also provide important background for Core Idea LS4: Biological Evolution, and can be related to Core Idea LS1B: Growth and Development of Organisms.

These lessons are aimed at students in 3rd grade, but could easily be adjusted for earlier and later grades.

These lessons assume that students have background knowledge of related DCI's from earlier grades), particular:

LS2.A: Interdependent Relationships in Ecosystems

- Plants depend on water and light to grow.

LS3.A: Inheritance of Traits

- Young animals are very much, but not exactly like, their parents. Plants also are very much, but not exactly, like their parents.

LS3.B: Variation of Traits

- Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways.

Lesson 1: Recognizing and measuring variation

Student learning objectives: By the end of this lesson, students will be able to:

1. Identify plant organs in an unfamiliar specimen (leaf, stem, root, flower, fruit).
2. Using non-technical (or technical) terms, describe characteristics of a plant they observe, including size, shape, leaf characteristics, and flower or fruit characteristics.
3. Sort plants into groups of similar and dissimilar individuals, and justify the groups using evidence (i.e., observations).
4. Identify differences among individuals within a group of similar plants.
5. Speculate about potential sources of variation between and within groups of similar plants.

Give a list of longer leaf describing terminology in case they want to use it if interested.

What needs to be done ahead of time:

- Plant a garden bed with appropriate plants. Starts (small plants) can be planted right before the lesson, but seeds would need to be started many weeks before. Many kinds of plants could work and what is appropriate will depend on the school's location and time of year the lesson is planned for. Suggested planting for N. Florida for mid fall lesson could be bush beans and kale, winter/spring could be lettuce/kale/spinach. The goal is to have two or three different crops that can be easily, but not so easily distinguished that it seems silly to ask students to think about what groups they go in (e.g. you don't want two similar varieties of lettuce, and you don't want kale and corn).

- Consider planting some of each type of plant in pots - these can be offered as sacrificial plants for students to crush, tear, or otherwise manipulate as they explore the different kinds of plants.

- The teacher should take some time to observe the plants and take some measurements of them to get a feel for what children might notice and how to direct their attention.

- Gather some rulers, clipboards, pencils and anything else for measuring plants and recording data, in case you have time for this.

- Take a look at the list of plant trait terminology in the Resources section and think about what vocabulary you might want to have on hand, or want to set as a goal for students to learn.

Location: In a garden space with rows or group plantings of several different plant species

Narrative:

> **Have students take a moment to take in the colors and scents and the variety of the garden.** Consider starting class with breathing to get centered and grounded to open our senses to our surroundings.

Ask student how the plants we see in the garden are similar and different from each other. Beginning with a very open question is useful because we want students to think of a variety of ways in which plants might be the same or different, e.g.

- height, habit (tree, shrub, herb, vine, damage (leaf-holes)
- leaf characters- shape, color, texture
- flower or fruit characters

You might encourage the students to look around more, touch, smell, etc. Here is where you could offer some expendable plants in pots that they can crush or handle as they like.

As students what are some reasons that plants are different or similar to each other? ...(and then to prompt more ideas "what makes you think that? Or "Can you show us what you mean?")
Differences/Similarities they might think of and that you want to prompt:

- plants are different "kinds", "types", "species"
- plants might have the same or different parents
- plants might be the same or different ages
- plants might have grown in similar or different environments (water, light, soil, density, insects, etc.)

As students how many different "kinds" of plants do you recognize in the garden bed and what is your evidence for recognizing a group or kind of plants

Students offer evidence: leaf characters, height, color, texture, etc.

Summary point to make to students: We recognize group or kinds of plants by shared characteristics/attributes. Lettuces look like other lettuces more than they look like other kinds of plants. Kale look like kale more than they look like other kinds of plants.

Now ask students to look at one kind of plant that the class recognized. What are some similarities and differences we see within this kind? Are they all the same?

Point to get to in discussion is that they are not all the same, and can vary in traits such as size, number of leaves, damage by insects, age

Ask students why might we see differences even within kinds?

Points to bring out: Age, health, environment (water, crowding, shade, insect damage)

If time available, take some data, as practice for the next lesson: Ask students how they would provide evidence on paper that their groups are different. Have them try writing down data on traits that vary within and across kinds of plants on index cards color-coded by species; this is practice for making a graph showing clustering of similarity around "kinds", which they will do in the next lesson.

Conclusion to draw by the end: we see variety in plants. Plants of one "kind" are more similar to one another than plants of different kinds, but don't seem to all be the same. We can make measurements of plant traits that we can use to describe the amount of variation within and among kinds.

Lesson 2: Visualizing information on variation, thinking about how traits vary between groups, but also within groups.

Student learning objectives: By the end of this lesson, students will be able to:

1. Distinguish between quantitative and qualitative traits.
2. Accurately measure quantitative and qualitative traits in plants.
3. Accurately record measurements of plant traits.
4. Describe the shape of a histogram.
    a) Identify the most common value for a trait in a histogram.
    b) Describe the amount of variation in a histogram. (too hard to do on just one histogram?)
    c) Evaluate the symmetry of a histogram (useful? Ties to stats ideas of normal distributions, though at this age it would be more about patterns, different kinds of shapes to these curves, not naming them…)

What needs to be done ahead of time:

- Teacher should make some measurements and try making histograms so they have some idea of how the process will work.
- Make sure students are already familiar with histograms from previous lessons in science or math
- Gather colored index cards, clipboards, pencils, rulers and other measuring devices.
- Need to be enough plants for students to measure separate individuals- so for 18 students preferably a minimum 18 of each kind of plant, or have students pair up so 9 of each kind.

Location: In the garden and then classroom.

Narrative:

Segue from previous class: Last time we were talking about how to recognize different kinds of living things. You suggested some traits that we could measure to tell plants apart and you took some measurements. Now let's see if we can figure out which traits help us tell apart groups we know are different.

Focus students on a pair of two kinds of plants in the garden-give them 5 minutes to observe and consider traits to measure.

Come together as a group and select 2-3 plant traits to measure across kinds

- Thickness of stem at plant base
- Length of leaves
- Number of leaflets
- Leaf color (using paint chips)
- Number of leaf lobes
- Hairy or not hairy
- Length of internodes
- Petiole length

Students measure some selected traits and record on index cards of different colors (one color for each plant "kind"). For example each student or student pair measures the traits from an individual plant. If students measure length of the longest leaf on each kind of plant, each plant would get one index card with its leaf length written on it (if important to students to retain ownership, can write name on data card). Or for a categorical example, each plant could have a card that said either "green stems" or "purple stems".

In classroom, show an example histogram . This can be one that they have seen in another context. Walk through how to interpret a histogram (check 3rd grade math standards).

In classroom, start to make histograms representing variation in traits. Write your axes on the board and put a card or two on for just one species.

Lesson 3: Going from variation between groups to parent offspring relationships

Student learning objectives: By the end of this lesson, students will be able to:

1. In a group, construct a histogram of plant traits using manipulatives.
2. Compare two histograms, and identify similarities and differences in terms of shape/distribution and overlap.
    a) Determine which histogram represents a group with more variation.
    b) Determine how much the most common value for a trait differs between two histograms.
3. Use histograms to determine whether two groups of plants differ in a particular trait.
4. Identify traits that can be used to distinguish two groups of plants, using histograms of those traits for each group.
5. Predict the parent for a group of offspring, using prior knowledge/intuition about resemblance between relatives.
6. Something about offspring resembling parents or siblings???

What needs to be done ahead of time:

- Look at data collected by students last class to anticipate what histograms using different traits will look like (in particular what the range of the axes needs to be).

Location: In the classroom.

Narrative:

Use color-coded index card histograms to visualize variation by constructing the histograms. Students are engaged in process by redistributing data cards to them. They take turns adding cards to appropriate bin on histogram. Each card should be somehow stuck to the board to form the histograms. If you chose three traits and had two types of plants to tell apart you'd make three pairs of histograms (one for each trait).

Use evidence from the histograms to discuss which traits seem most useful in telling these plants apart. Try to get to the fact that some traits are more variable than others (have a wider range), some are more different between plants (means differ more).). Expect that there will be overlap in range for traits for some or all of the traits. Note any traits that seem to clearly separate the kinds of plants. Combination of traits are used to distinguish plant kinds- might not be the traits that we looked at.

Discussion: Why is it that different types of plants look different? Why does a lettuce plant look like a lettuce plant- and a kale plant like a kale plant? (getting to seeds came from parents that were lettuce or kale, and maybe to similar environments). Focus them on parent/offspring similarity.

Can we tell which offspring go with which parents? Card sort activity in the classroom. Have cards with pictures of adult dogs and their puppies. Ask them to put the cards into which offspring with which parents. Note that some students may be part of non-genetically based families so approach discussion of human families with sensitivity to the fact that not all families would be expected to look alike.

Wrap up: Today we found that we could use plant traits to tell different kinds apart and some traits were more useful than others. Then we talked about why the plants of each kind look

similar to each other, and we noticed that with puppies we could recognize that pups share traits with their parents and with their siblings.

Lesson 4: Quantifying differences in traits among family groups / similarity within family groups

Student learning objectives: TBA

What needs to be done ahead of time:

- Materials needed include sunflower seed head, or pictures of adults with seeds, Trays with individual parents, and trays with a mix of parents, Some example seedlings for other plants

Location: In the classroom.

Narrative:

Last week we sorted families of dogs, and we saw that families tend to look similar to each other. Plants also have parents – can we sort them the same way? How might we do that? Brainstorm with students, hopefully arriving at the idea that they could measure traits of offspring.

Tell the students that you got seeds from 4 families for this activity (4 packs of seeds of cultivars of the same plant species). Ideally, have an adult plant (or part of plant) with seeds on the plant so they can see that seeds are from a particular parent. If no adult plants available can use pictures of adult plants with seeds on them.

Students have proposed using traits to sort plants. Can we do that? Can you give me evidence that you can use traits this way?

For this activity we will suggest specific cultivars of beans (one option) or sunflowers (another option).

Activity: give the students tools for measuring the seeds, encourage them to quantify differences somehow. Visualize the data as a group (histograms of seed sizes?)

→Oh no, they don't really sort! (choose plants where seed size doesn't sort them clearly into cultivars). What else can we do to find out which parents they go with? (let the mystery stand: could we plant them?)

Design an experiment to see if you can sort the seeds to the right parents once they are seedlings. Okay, say we plant them, how will we tell them apart? What should we measure? How will we plant them?

Students decide what traits to measure. Focus them on seedling traits.
Teacher has example seedlings in class to show (good idea!). If the students ask what the parents look like, give some information (pictures of adult plants?).

- Traits students might think of (or teacher can suggest):
  - Shape of cotyledons
  - Plant height
  - Petiole length
  - Number of leaves

        - Color observations
        - Thickness of stem
        - Length of leaves
        - Length of internodes
        - Width of leaves
        - “Roughness” of leaf edge
        - Above ground biomass (and talk about what leaving the roots are doing, or look at nodules)
        - Hairs on leaves or stems
    - Time to germination is a good one, or time to first true leaves or cotyledon senescence, but likely won’t be thought of by kids? Maybe lead them to this?
        - Maybe ask students: when do you think we will need to start making our measurements? Will it be the same for all of these plants? Might it be different?

Students decide how to plant them. This could be in the classroom in dixie cups or in the garden. Allow them to leave things less than perfectly controlled - you want some room for environmental variation to affect the seedlings. You could amplify this by providing cups of different sizes, or not enough room on the windowsill so there is variation in light.

Tell the students that to make this a fair test you are going to have another teacher come in and cover up all the labels so no one in our class, including me (the teacher) will know which is which. Then we will see if your ideas about traits will actually sort them out.

Wrap up discussion: we have the hypothesis that offspring share traits with their parents, and their siblings. We think we can figure which families even plants belong to by measuring traits. Next time we will plan our experiment to see if traits will really tell us this.

Lesson 5: setting up the inheritance experiment

Student learning objectives: TBA

What needs to be done ahead of time:

- If working in the garden, prepare a cleared area for planting.
- Gather materials. For an experiment in the garden, need seeds, markers. For an experiment in the classroom, need pots (dixie cups, jars, pots), trays for putting them in, soil, seeds, markers).

Location: In the garden or in the classroom depending on what you have available

Narrative:

Introduction: During the last class we decided upon a plan to sort seedlings into families based on their traits and to thereby test our hypothesis that parents share traits with their offspring. This is a good time to discuss the importance of controlling for unwanted variables. Some guiding questions a teacher could ask include: "How should we plant the seeds? How many should we put in each pot or what distance apart should they be planted? At what depth should they be planted?" Some of these **environmental** variables (word choice) could have a big influence on the traits of plants, so we need to keep them consistent. Write on the board what you decide for plant depth, number of seeds, distance apart, etc.

If you're setting up the experiment in pots:
Action: Divide students into groups of 3-5. Each group should have access to pots, soil, sharpies, colored plant labels [give each group a different color], a set of seeds in a Petri dish, and a ruler. Students should then be free to plant and label the seeds themselves. As new questions come up (e.g., where should we place the pots?), return to the group and discuss how to control for these other factors.

If you're setting up the experiment outside:
Action: Divide students into groups of 3-5. Groups should be assigned a small plot in the garden bed (probably not larger than four square feet) and may need to spend a few minutes clearing weeds and preparing the soil (gloves and hoes may be required for this). Once cleared, teachers will hand out bags or dishes of seeds to each group (5 seeds per student?). Students will plant seeds the predetermined depth and distance apart. Each seed will be labeled with a plastic plant label and a sharpie.
Come back together as a class: What did we observe while planting the seeds? Was there anything unexpected that we think might affect our results?

Important: As a class have students design a datasheet for recording information. Setting up the sheet makes it clear what needs to be measured when, and by whom (students continue to measure their group of plants).
Discuss: Expectations for the results.

Wrap up:

Lesson 6: taking data from the experiment and interpreting it, introducing environmental variation

Student learning objectives: TBA

What needs to be done ahead of time:

- ?

Location: In the garden or in the classroom depending on what you have available

Narrative:

Taking data might happen a little at a time, or all at once depending on what is being recorded

Use the data to make histograms again.

Get out the seed packets again - can we tell which of our little plants came from each pack? Seems to me we have a problem here - we might get clear groups, but not be able to associate them with parents. Whether this works will depend heavily on the cultivars chosen.

Are siblings more similar than nonsiblings? Are there particular traits that we measured that parents seem to pass on to offspring? Are we sure that siblings are more similar? How much variation is there?

We do see groups that sort, but look at how much variation within groups. Why don't all the sibs look just alike? Where is that variation coming from? Environment! Maybe refer back to earlier lessons where hopefully environment came up.

What environmental factors might have influenced our little seedlings (light, water, pot size, etc.)?

Lesson 7 and beyond: environmental variation

Student learning objectives: TBA

What needs to be done ahead of time:

- ?

Location: In the garden or in the classroom depending on what you have available

Narrative:

The following outline is from Lindsey:
Engagement:

- Building on the topic of inheritance, would we expect there to be variation among organisms that have the same genetic make-up (same parents)?
- (In the garden) Do we see differences among individuals of the same species? Where might these differences stem from?
    - Looking at the garden and comparing genetically similar plants, ask students to notice any differences between like plants. Try to highlight both qualitative and quantitative differences.
    - Ask students what might account for these differences (how much sunlight they get, how much water they might get, etc.)
        - (This part might be more meaningful/ successful in a field or area at the school that has more variable sunlight, rainfall, foot traffic, inclines, etc.)
        - Students should support their hypotheses with evidence.
            - Hypothesis: perhaps being in the shade makes plants smaller
            - Evidence: I saw some small plants in the shade
        - How strong is this evidence? Are there alternative explanations?

- (In the classroom) Teacher gives lesson about variation of traits
    - From NGSS expectations for grade 5: Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment.
    - With this information, aid students in designing an experiment where students manipulate one environmental variable and observe what effect, if any, it has on the plants' traits and how we can observe this through quantitative measurements.
        - For example, students might want to see how the height of a bean plant will be affected by the amount of sunlight the plant receives.
        - Use 1 family group (seed pack) and just two or three environments. Keep it simple.

Explore:

- (In the garden) allow students to set up their experiment and plan how they will carry it out over the course of a few weeks.
- (In class) Students fill in worksheet that might have questions such as:
    - What environmental trait are we manipulating?
    - What do we expect to happen? Why? What did we see in the garden (or field) that would support this prediction?

Explain:

- Students create a model to explain the findings of their experiment (creating a line plot with a correctly labelled horizontal axis is a common core standard expected of this grade level).

Materials:

Lesson 1

- Access to outdoor area/garden with closely related plants
- Different colored index cards
- Tools for measuring: rulers, scale (magnifying glass or microscopes may be useful if available

Lesson 2

- Writing utensils and chalk board/white board for making graphs
- Tools for measuring: rulers, scale (magnifying glass or microscopes may be useful if available

Lesson 3

- Assorted colored index cards
- tape
- card sort activity requires cards with photos of dogs/puppies or trees/seedlings

Lesson 4

- Seeds of 4 different cultivars of two species (beans and sunflowers)
- An adult plant of each of the above species (just two, one bean and one sunflower)
- Tools for measuring: rulers, scale (magnifying glass or microscopes may be useful if available), calipers, paint chips, hair density pics?

Lesson 5

- pots for indoor growing of plants or garden bed outside
- Irrigation equipment for experiment, this could be as simple as a hose or watering can
- datasheet for recording observations

Lesson 6

- graph making materials again

Lesson 7

- powers of observation!

Resources:

Background reading about variation, inheritance, etc.: Any suggestions?

Seed and plant sources: Talk to the managers at your local nursery, or order seeds on-line. Some good sources for seeds include:

- Park Seed (Parkseed.com)
- Renee's Garden (https://www.reneesgarden.com/
- Burpee (www.burpee.com)
- Jonny's Selected Seeds (http://www.johnnyseeds.com/)

Citizen Science tie-in: If using Lemon Queen Sunflowers, these lessons could be combined with participating in a citizen project monitoring pollinators: https://www.greatsunflower.org/

Sources for supplies: The only unusual piece of equipment mentioned in these lessons is a dissecting microscope or other magnifyers. Paper microscope?? Calipers?

Sources for expertise: If you are not already an expert gardener, you can find advice on good plants for your location and season, and on how to care for your garden from your local county extension office's master gardener or school garden program (if they have one), or from local plant nurseries. If your school is located near a research facility (e.g. college, university or agricultural experiment station) we also encourage you to contact local biology researchers who work on plants or agriculture. Scientists are generally happy to answer questions and even visit classrooms and partner with teachers! To find a local researcher, look for web pages for departments of biology or ecology and evolutionary biology and then look for a page listing the faculty. Each faculty member usually has a page describing their research interests and giving contact information so you can pick out someone to contact. Or you can contact the department secretary by calling the main number for the department and describe the kind of help you are looking for and they will connect you with someone appropriate. Both faculty and their graduate students can be great sources of ideas, expertise and collaboration in the classroom.

Alternative to using food plants in a garden: There are plants that have been developed for experiments in the classroom. They are not food plants, and they are a bit expensive, but for some kinds of situations they could work very well. They are called "Wisconsin fast plants" and you can read about them here: https://fastplants.org/.

List of plant terminology: There are many many very specific terms for describing what plants look like. If you want to be overwhelmed, see these glossaries: http://www.calflora.net/botanicalnames/botanicalterms.html or https://florabase.dpaw.wa.gov.au/help/glossary#P. While most of us have little use for much of this terminology, having some language to describe what they are seeing may help students be precise in their descriptions and help them feel knowledgeable about plants. Here is a short list of terms other than the obvious "roots, stem, leaf, flower, fruit" that might be useful with students of this age.

> Petiole: the stalk of a leaf.
> Alternate versus Opposite: describes how leaves are arranged along the stem, either emerging from the stem in pairs with one leaf petiole attaching to the stem opposite the other, or emerging from the stem singly and alternating sides of the stem.

Axil: the angle where a petiole or branch emerges from a stem. Often there is an axillary bud at the axil. This bud might produce a flower stalk, or a new branch.
Trichomes: tiny hairs that can grow on leaf or stem surfaces. Some of these are very cool to look at with magnification! See here: https://en.wikipedia.org/wiki/Trichome. Leaves without trichomes are called "glabrous" and leaves with trichomes are called "hirsute".
Margin: the edge of the leaf. Margins can be "entire" (meaning smooth) or "toothed" (pointy projections from the margin) or "lobed" (large smooth ins and outs along the margin), and the toothed ones come in lots of types, see here under "margins": https://en.wikipedia.org/wiki/Glossary_of_leaf_morphology
Leaf shape: leaves can be long and skinny or short and fat - there are lots of terms for shape: https://en.wikipedia.org/wiki/Glossary_of_leaf_morphology. Leaves can also have just one part (simple) or several (divided into "leaflets", e.g. "trifoliate" like a clover): https://en.wikipedia.org/wiki/Glossary_of_leaf_morphology
Internodes: This is the length of stem between one leaf and the next. This can vary a lot, for instance in lettuce there are no obvious internodes (all the leaves come out pretty much in the same place) whereas in kale there are clear internodes between leaves.
ETC.

Assessments:

Assessment

Name:

Teacher: _____

Period: _____

Our friends John and Anna want to grow zinnias to sell at the market. They are able to charge $1 for every individual cut flower. The zinnias grew fast and were healthy and large, but they were disappointed to see that many of the plants grew only a few flowers. Because they don't have a large garden, they want to only grow zinnias that grow lots of flowers on each plant.

Directions: Examine the data table below and think about what you know about the traits of parents and offspring. If John and Anna start their garden over using this first set of plants as parent plants, which plants would you suggest they collect seeds from and why?

	Number of Flowers
Plant A	2
Plant B	5
Plant C	2
Plant D	6
Plant E	5
Plant F	2
Plant G	3
Plant H	3

Assessment 2: using leaf shape to group plants:

https://drive.google.com/file/d/0B5G9C8VDtmh0azBxcFZsN2lDbWs/view

Assessment 3: For Lesson 3: Have students add cards to histogram- then Think-Pair-Share response to question "Use evidence from the histograms to discuss which traits seem most useful in telling these plants apart."