**Overview & Guiding Questions**

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

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

**Objectives**

***Ecological Understanding***

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

***Scientific Process***

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

***Sense of Place***

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

**Time Required**

80 minutes

**Supplies**

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

**Preparatory Activities**

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

**Classroom Activities**

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



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

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

What are some different ways we can summarize our data to make it easier to answer our research question?

How do you calculate an average, and why are averages useful?

How do group size or skewed data affect averages?

During Lesson 7, the UCD team should collect the Plant Growth Datasheets from all teams. The UCD lesson 8 team should use the datasheets to calculate the class-wide average plant height for the earliest day when all (or most) of the plants had emerged. This average will be given to the class in section 3e, when they fill in the third section in Experimental Log 8. Alternatively, the UCD team can use data from a previous year or for a single class if there is insufficient time/hands to collect the real data.

**LESSON PLAN OUTLINE**

**Adapt This!**

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

1. INTRODUCTION AND DISCUSSION (15 MIN)
2. GROUP DISCOVERY EXERCISE (20 MIN)
3. CALCULATING AN AVERAGE PLANT HEIGHT (20 MIN)
4. PLOTTING AVERAGE PLANT HEIGHT DATA OVER TIME (15 MIN)
5. WRAP-UP DISCUSSION (10 MIN)

**LESSON PLAN**

1. **INTRODUCTION AND DISCUSSION (15 min)**
   1. *You have all been busy measuring your experimental bean plants and plotting your height measurements over time.* Question: *Why are you doing this?* (Answer: To test your hypothesis that plants will grow differently to serpentine and loam soil.)
   2. *So far, do you think that bean plants grow better on serpentine (*count hands*), on loam* (count hands*), or does it seem like the plants don’t care or you don’t know (*count hands*)?*
   3. *Chances are that none of you feel completely certain about your answer so far. What are some of the reasons?* (**Write on board:** e.g. different groups’ plants didn’t grow the same, plant size varied within pots/treatments, plants are hard to measure well, the treatments don’t seem to make a big difference, etc…)
   4. *Let’s find out just how variable the heights of our plants were within each treatment.*
      1. *Everyone, what was the last day on which you measured the height of your bean plants?* (Look at the last measurement day on the Bean plant growth chart.)
      2. Starting with one team, ask for their tallest and shortest measurements on each soil type. List these data points on the board in two columns labeled “serpentine” and “loam.” Ask if any group has a shorter or taller measurement for either soil type. The goal is to discover the shortest and tallest measurements in the entire class for each soil type.
      3. *What is the shortest plant we’ve seen growing on loam? What is the tallest plant on loam? What is the shortest plant on serpentine? The tallest plant?* (These measurements are circled on the board.)
   5. **Experimental Log Question 1:** How big was the difference between the tallest and the shortest plant grown on each soil type (what is the **range** of values)? Based on circled measurements on the board, teams will fill in the table on their **Experimental Log** to answer this question. (Question 2 will be answered after the Group Discovery Exercise, during part III.)
   6. So now that we have all of these numbers up on the board, it might be hard to tell whether one soil led to taller plants than the other since there is so much variation. *Can you think of any way we might be able to summarize all of this data to see if serpentine or loam soil led to larger plants?* If this not mentioned, point out that we can take the average to find out the answer (it is unlikely that they will have heard of this). *One way we summarize the group is to calculate an average. And you are going to figure out how to do it!*
   7. *An average is a number that summarizes a lot of different data points. Averages help us make predictions—for example, if we knew the average height of a 5th grader, we’d be able to guess pretty well how tall a kid in this class is likely to be. That number might help us if we want to pick out desks and chairs for the classroom, or help us understand how much kids grow between 5th grade and 9th grade.*
   8. *This is a hard concept to understand, so we’re going to do an activity to help you understand how we calculate and use averages.*
2. **GROUP DISCOVERY EXERCISE—CALCULATING AVERAGE HEIGHT WITHIN GROUPS (20 min)**

**Adapt This!**

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

* 1. *When a scientist tests hypotheses, she usually need to compare the characteristics of different groups—those groups may have been exposed to different experimental treatments (like your plants), or they may have had different histories that you did not control.*
  2. *Let’s imagine that you are all a big team of scientists, and you’d like to know whether people who prefer chocolate ice cream or strawberry ice cream are taller. Remember when we made a hypothesis about the bean plants and their heights. Do you have a hypothesis (a prediction) for whether people who prefer strawberry or chocolate ice cream will be taller? Why? Let’s say that we hypothesize that people who prefer strawberry are taller because strawberry ice cream is more nutritious. To figure this out, we’d have to do an experiment, right? That would require a lot of ice cream, and time, and all sorts of permission from you and your parents, and a lot of effort (Scientists DO this with people, for example, when they are testing new medicines!).*
  3. *What we can do, for now, is to compare the heights of the students in this class who prefer chocolate or strawberry and see if we have a trend. We’re going to need some volunteer test subjects here for our study!* Have students who prefer chocolate raise their hands, randomly select 7 of them to go to one of side the room, then repeat with strawberry but use 6 or 8 students.
  4. *This isn’t exactly a perfect study, but for now, we’ll figure out how we can tell which group is taller, on average.*
  5. *For starters, can we just look at the groups and tell which group is taller?* Discussion.
  6. *Can we just measure the tallest student in each group? Or the shortest? And then decide based on that?*
  7. *Somehow, we need to “see through” the variability within each group to figure out which one is taller, on average. To do that, we need to measure each person in each group and then figure out how to summarize all of those heights.* The volunteer instructors and teacher help to measure each student; write down the heights as two columns of numbers on the board.
  8. *Now what do we do with all of these numbers to compare them? Maybe we need to add up all of those heights within each group… if there are lots of tall students in the group that will be a bigger number.* Add up the heights for each group, and write the total on the board.
  9. *But, can we really compare these two totals?* Lead the students to realize that the comparison isn’t fair, because there are more students in one group than in the other.
  10. *What can we do to make the comparison between the two groups “fair”?* Lead the students to the idea that you have to divide the height total by the number of students in the group. This is the average height for a group!
  11. Volunteer instructors displays the method for calculating the arithmetic mean of a group on the Smartboard, leaving it up for reference by the students.
      1. Count the number of individuals in the group
      2. Measure each individual
      3. Add up the measurements for the whole group
      4. Divide the total by the number of individuals in that group
  12. *So we’ve found that the group that likes \_\_\_\_\_ ice cream better is taller. But what if one short person who liked \_\_\_\_\_ ice cream transferred into this class – would that be enough to change which group is taller on average?*
  13. If there is time, expand on the discussion by adding a teacher or volunteer instructor (significantly taller than the students) or ask what would happen if we added in a pet or younger sibling. Lead students to the conclusion that an average is brought up or down by bigger or smaller numbers and that extreme values can skew the result and make prediction more difficult.
  14. *What do you think – if we knew the heights of everyone in the world who prefers either strawberry or chocolate, do you think we’d still get the same result? Why or why not? In other words, do you think there’s a real reason that people who prefer \_\_ ice cream are taller, or do you think it’s just a coincidence that people who prefer \_\_ in this classroom happen to be a little taller?*

1. **CALCULATING AVERAGE PLANT HEIGHT (20 MIN)**
   1. *Now let’s do the same thing for your bean plants! This is how we can determine which treatment is really doing better overall than the other in terms of heights.*
   2. The first step is for each team to calculate the average height of its three serpentine bean plants and its three loam bean plants.
      1. The volunteer instructors work out one example on the board, using three hypothetical heights.
      2. Each team uses its most recent plant growth data sheet and the Lesson 8 Experimental Log to calculate the average heights of the plants growing in their serpentine and loam pots. Use the most recent heights that you measured, and fill in the table on the experimental log (**Experimental Log Question 2**).
   3. *Let’s read out the averages that each team calculated!* 
      1. Write these on the board (next to the individual plant measurements).
   4. Discussion: *OK, now let’s say we want to know whether or not serpentine or loam plants are taller for the entire class’s data? How could we calculate that?*
      1. We calculate the average bean plant heights for the whole class by taking the mean of all team averages.
      2. The volunteer instructors demonstrate this, with help from student teams, for the most recent height data in the serpentine and loam soil treatments. These new whole-class means for each measurement day and soil type should be written on the board and circled.
      3. Is the average plant height for the whole class (say, on loam soil) higher or lower than the average in your team’s pot? (Teams call out, in turn, demonstrating that some will be higher and some will be lower.)
   5. *Now let’s fill in the table of data that summarizes all of your whole classroom’s bean height growth data.* Below, each team should fill out the table of summary data on their Experimental Log (question 3). Remember that THIS table is for all the class’s height measurements, not just the data for individual teams.
      1. **Experimental Log, Question 3:** *We will fill in the table with our whole-class height averages for two measurement days.* The first is day \_\_\_ (the volunteer instructors will have chosen a day and calculated the class average earlier). We could go through the same process to calculate the class averages for that measurement date. That would take a little too long today, so we calculated the average for you.
      2. The second blank row in the table is for the most recent measurement day. *We just calculated the average heights for our serpentine and loam treatments on our last measurement day, and they are written on the board. What was that measurement day?* Fill those averages for that day on the table.
2. **PLOTTING AVERAGE PLANT HEIGHT OVER TIME (15 mins)**
   1. *Wow, we have been doing a lot of math! It’s time to remember WHY we need to summarize our plant growth data this way!* (To help us see patterns that will test our hypothesis.)
   2. *In your binders, take a look at the graphs you have made so far, plotting the growth of your team’s bean plants in each soil type. Because individual plants are growing differently, imagine how confusing it would be to try to look at all of those graphs for all of the teams at once!*
   3. *Now, instead of plotting individual plant height measurements, we will plot average plant height over time for BOTH of our soil treatments on the same graph. This will help us to consider the question that motivated our experiment—do plants respond differently to these two soil types?*
   4. On the SmartBoard, show the calculated class mean values and have students complete the table in **Question 3**.
   5. Next, on the SmartBoard, display a blank growth chart. Using the means written into the table for **Question 3,** the students are shown how to plot the height means over time, giving two different symbols for the serpentine treatment and the loam treatment.
   6. With help from volunteer instructors, each team now plots the class average data for both treatments on a single graph (Experiment log **Question 4**). While students are filling in their graphs (IN PENCIL!), the Smartboard graph is also completed, except for the lines connecting the means within each treatment.
   7. Now, let’s use our new summary XY graph!
      1. *Notice that it is easier to see differences between treatments if we connect the plotted means within each treatment by lines.* (Demonstrate this on the Smartboard.)
      2. *Those lines allow us to see quite easily how fast plants are growing over time. A steeper line means faster growth! Based on this graph, do you think that bean plants are growing faster in one soil? If so, which one?*
3. **DISCUSSION AND WRAP-UP (15 mins)**
   1. *Which plants grew taller on average – the ones we planted in serpentine soil or loam soil?*
   2. *What are some possible reasons that the plants on (serpentine/loam) grew taller?*
   3. *Today we learned a strategy for summarizing the data for lots of individuals: calculating an* ***average****. We’ve posted on the SmartBoard a graph of lots of individual plant heights. Which plants grew taller: the ones on serpentine or loam?* (Vote by raising hands).
   4. *Okay, here’s a graph showing just the average plant heights. Now which plants do you think are taller? (Vote by raising hands).*
   5. *Which graph was easier to understand: the first one, with all the individual plants, or the second one, that just showed the averages? What information does the first graph give you that the second does not? Is one better than the other? Why or why not?*
   6. *Revisit your hypothesis—do our results support your hypothesis? Why or why not?*
   7. Finally, review how to calculate an average and discuss why this is a useful tool. *How did averages help us answer our research question?*

**Assessment for Lesson 8**

**Team/Student Name(s):\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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