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The Bio/Diversity Project

Introduction to Sonoran Desert Pollinators

Teacher: Lily & Grace
Grade Level: 9th
Time Teaching: 50 mins

This lesson has been adapted from: Flowers Seeking Pollinators and Pollination Investigation Field Journal

AZ Science Standard:	Cheat sheet for AZ science standards *HS.L4U1.27* ● *Obtain, evaluate, and communicate evidence that describes how changes in frequency of inherited traits in a population can lead to biological diversity*
Learning Objectives:	1. Students will be able to predict and confirm why flowers attract specific pollinators 2. Students will be able to explain to a friend why pollinators and plants need each other
Scientist of the Week:	● *Dr. Kathleen Prudic* ●  ● *Entomologist, co-director of eButterfly,* ● *Tucson, AZ* ● "I study where pollinators are, what they are doing, and how we can help them in a rapidly changing world using citizen and data science techniques." - Dr. Prudic

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Vocabulary	Materials
• Pollination • Biodiversity • Fertilization • Ecosystem • Keystone species	• Google Slides Slideshow • Class set of blank paper • Blooket • Fill in the blank worksheet for student journals (3 pages or one copy of this document per 2 students. Worksheets should be cut in half on the line, so each student gets 3 half sheets.) Data literacy activity: • Printed sonoran desert-adapted data sheet • Printed pollinator profile cards • Printed constructing explanations worksheet **Student count:** 105

Seasonality: Any seasonality

Monsoons July-Sept.	*Autumn* Oct.-Nov.	*Winter* Dec.- Feb.	*Spring* Mar.-Apr.	*Dry Summer* May-June

Guiding Questions:

- *What does pollinator diversity look like in the Sonoran Desert?*
- *What kind of impact do pollinators have on ecosystem function and productivity?*

Engagement/Introductory Activity:
Ice breaker activity: Flower Competition

- Students gather into small groups of 3-5 people, with those at their desk pods.
- Pass out a blank piece of paper to each group.
- Students assign one writer per group.
- Teachers set a 2-minute timer.
- Students think and write as many types of flowers as they can until the timer goes off.
- Students grade their paper, counting up how many types of flowers they thought of.
- Student teachers ask the students reflecting questions: Why are there so many different flowers? What are some differences between the flowers they listed? How do these flowers spread/reproduce?

Exploratory Activity:

Data Literacy

- Split students into pairs and instruct them to sit together (if they are not already. It helps to use students sitting next to each other at a table already so students don't have to move seats.)
- Assign each pair of students a pollinator: bee, bat, bird, butterfly, moth, or fly.
- *Pass out the* ***Pollinator Data Observation Sheet***
- Students should take the time to read the descriptions of all the flowers and look at the data before answering the questions. On the back, they will answer the following questions:
    - *Who is your pollinator?*
    - *What flower did your pollinator visit the most?*
    - *What are three flower traits that you think attract your pollinator?*
    - Let students know that they are beginning to construct explanations about what flower features attract their pollinator. Their current explanations are only based on observations in the field, which is exactly how research scientists build their explanations. Next, they will receive more information about their pollinator to modify or strengthen their explanations.
- Pass out the Constructing Explanations sheets (1 per student) and the Pollinator Profile cards. Each group should get the Pollinator Profile that corresponds to their pollinator.
- Once students have read their Pollinator Profile, they will write down 3 flower traits that are attractive to their pollinator on the Constructing Explanations sheet. This time, they will have more information to use, so remind students to consider the following:
    - Compare the information in the profile to the data gathered from pollinator observations. This can indicate if it's a trait that the pollinator is attracted to, or is a trait the flower has for a different reason.
    - Encourage students to not just look at the data from the flower their pollinator visited the most but look at trends amongst all the flowers. For example, bees went to Flower 2 the most, but they also went to Flower 6 – do Flowers 2 and 6 have anything in common?
    - These may end up being the same 3 traits that they wrote down earlier, but they need to be supported by the information they just learned about their pollinator.

Explain:

- Bring the whole class back together and debrief.
- Present discussion questions.
    - *Why are pollinators important to ecosystems?*
    - *Why are pollinators important to humans?*
        - *Pollinators are important because they provide plants with the proper pollination, which is needed for plants to reproduce and produce flowers and any agricultural foods. When we overlook certain pollinators, we overlook the important work they do.*

Extension Activity/Questions:

- On the computer connected to a projector, open up the blooket quiz.
- Select host, and then select the "classic" gamemode.
- Press "Host" again.

- Change the settings if you wish, but the default is okay. Press “Host now” to begin the game.
- Ask the students to navigate to play.blooket.com and enter the ID displayed on the screen.
- Once most/all students have joined, begin the game! Also, allow students to use their notes during the quiz to encourage note-taking during class.

Evaluation Activity:

- Have students discuss what answers they were surprised by, or what they got right.
- For example, the question about the weight of a Rufous Hummingbird- Ask students:
    - Why do you think they are so light? Did you think that they would weigh as much as a penny?
- The students should be able to explain why pollinators and flowers need each other. Ask them to think about why humans might need pollinators. Have them reflect on which of their favorite foods would not exist without pollinators! (Fruits, vegetables, nuts, etc.)

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The Bio/Diversity Project
Lesson Title: Hummingbirds as Pollinators

Teacher: Lily and Grace
Grade Level: 9th
Lesson Length: 50 min

Based on Existing Lesson Plans: Structure and Function: Hummingbird Tongue and Inquiry-Based Hummingbird Activities

AZ Science Standard:	*HS.L4U1.27* • *Obtain, evaluate, and communicate evidence that describes how changes in the frequency of inherited traits in a population can lead to biological diversity*
Learning Objective:	- *Students will be able to explain why hummingbird tongues and bills help them drink nectar from flowers* - *Students will be able to describe why hummingbirds migrate to Arizona*
Scientist of the Week:	• *Dr. Joseph Drew Lanham*  • *Professor, Cultural ornithologist, and poet* • *Clemson University in South Carolina* • *Advocates for the African-American role in natural resources conservation* • *Researches songbird ecology*

Vocabulary	Materials
• Hibernation • Migration • Pollination • Species Diversity	• *Slideshow* • *Class set of Observe, Describe, Wonder - Worksheet (105)* • *Class set of fill-in-the-blank worksheet (53)* • *A few pennies to pass around class*
Seasonality: Any	

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Monsoons July-Sept.	*Autumn* Oct.-Nov.	*Winter* Dec.- Feb.	*Spring* Mar.-Apr.	*Dry Summer* May-June

Guiding Questions:

- What advantageous characteristics do hummingbirds have for pollination?
- Why do hummingbirds migrate to the southern United States?
- How do hummingbirds impact their ecosystem?

Engagement/Introductory Activity:
Have the students watch a video about Dr. J. Drew Lanham, a cultural ornithologist. Then, we'll have students discuss what they already know about hummingbirds and ask questions as a group. This will be a good way for the students to start thinking about hummingbirds, leading us into our content for the rest of the lesson!

- *Here is the video. We chose to play the video from 3:52-5:28 since the video is 13 minutes long.*
- *After the video, ask the students a question:*
  If you were a bird for a day, where would you fly?
  Then, have them discuss their answers with their neighbor.

Exploratory Activity:

Observe, Describe, Wonder - Worksheet

The two-page format encourages inquiry-based exploration. In the first column, students look closely at a photo and describe details they notice. In the second column, they will ask a question inspired by their observations.

We will show the students three photos of hummingbirds in the slideshow presentation. Looking at the collection of pictures, the students will have one minute to make wonders and notices about the images, filling in their worksheets. While this is happening, we will model how to describe details and ask questions. For example, we will say, "look at images that capture a hummingbird in flight and think aloud: I noticed the wings look like a blur. How many flaps do their wings make in a second? How and why do hummingbirds hover in mid-air at flower blossoms? How do they get nectar from flowers? Which flowers do hummers prefer?" It is our duty to encourage students to wonder aloud and record their ideas on the Observe and Wonder chart.

Explain:

- *Make sure to explain how to make a hypothesis. What do students think the answer to their question is? What do they know about birds?*
- *Working with their group (2-5), students will form a hypothesis for one of their questions.*
- *As teachers, encourage students to ask follow up questions by giving them hints. Help students collect words and phrases they'll need to communicate their scientific thinking.*
- *This will then lead us into our slides about hummingbirds, which will answer a lot of common questions. How light are they? How fast do their wings flap? How do they migrate? How do they eat and drink?*

Extension Activity/Questions:

Play a video, Structure and Function: Hummingbird Tongue, where students will learn how the structure of

hummingbird tongues are specialized for their function of drinking nectar. Then, ask the class critical thinking questions related to the video.

Critical Thinking Questions

- *How was your experience discovering the structure of the hummingbird's tongue?*
- *Why do you think hummingbird tongues are structured to lap nectar so quickly?*
- *How often does a hummingbird have to feed, before it "runs out of fuel?"*
- *Why do the plants hummingbirds feed on only have a small amount of nectar?*

Evaluation Activity:

Have students complete a fill-in-the-blank exit ticket worksheet, which contains the following questions:

1. Hummingbird bills are shaped like: _____
so they can reach _____.

2. Hummingbirds _____ from Central America or
Mexico to the southern United States to _____.

3. Write your favorite hummingbird fact you learned today:
_____.

This will allow us to evaluate the students' understanding of the significant topics from the lesson and see what they enjoyed.

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The Bio/Diversity Project
Lesson Title: Introduction to R

Teacher: Lily and Grace
Grade Level: 9th
Lesson Length: 50 min

Based on Existing Lesson Plans: Students as Scientists

AZ Science Standard:	- U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.
Learning Objective:	- Students will be able to form a hypothesis that tests the time of day Rufous Hummingbirds most frequently visit CHS. - Students will be able to collect data by sorting through wildlife camera pictures in the computer lab.
Scientist of the Week:	● Dr. Meaghan Emery-Wetherell ● Vertebrate paleontologist who specializes in data analysis ● Assistant Professor at the University of Arizona School of Information ● Teaches English as a Second Language, Outdoor School, Geology, Biology, Statistics, Science Communication, and Environmental Science ● Resides in Washington state ● Meaghan's personal website ● 

Vocabulary	Materials
● Wildlife camera ● Phenomena ● Hypothesis	● Access to computer or laptop connected to the internet ● Zooniverse.org project page ● Students' notebooks and writing utensils ● Slideshow

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Seasonality: Spring because Rufous Hummingbirds migrate through Arizona at this time of year. Hence, students can sort through freshly taken wildlife camera photos shot in their school's courtyard.				
Monsoons July-Sept.	*Autumn* Oct.-Nov.	*Winter* Dec.- Feb.	***Spring*** **Mar.-Apr.**	*Dry Summer* May-June
Guiding Questions: ● *Why is it important to question the world around us?* ● *What skills or practices do scientists use to understand the natural world?* ● *What methods and tools do scientists use to collect data?*				

Engagement/Introductory Activity: Tucson Trail Cam Video

- After introducing wildlife cameras' functionality, purpose, and importance, students will vote on three one-minute "critter cam videos" they want to watch.
- https://exploretucsonmountains.com/tucson-trail-cam/
- This engagement activity aims to showcase wildlife footage of native Tucson species.
- Duration: 5 minutes

Exploratory Activity: Write a hypothesis

- Via presentation, students will learn what a hypothesis is and how to write one.
- We will define a hypothesis as a testable statement rather than a prediction, which is a common misconception.
- Students will format their hypotheses using the "I expect to observe A because B" format and then change the sentence to a statement by removing the "I expect" phrase.
- Interns will exemplify the process of writing a hypothesis using the steps above.
- Students will have five minutes to write their own hypothesis to the research question, "What time of day do Rufous Hummingbirds most frequently visit CHS?"
- Duration: 10 minutes

Explain: Think, pair, share your hypothesis

- "Share your hypothesis with your neighbor"
- "Does anyone want to share it with the class?"
- Students have the chance to communicate their hypotheses with others, which is an important part of science communication.

Extension Activity/Questions: Sort through wildlife camera data in the computer lab

- Students will head to the computer lab to sort through the footage our wildlife cameras picked up over Spring Break.
- When students access the zooniverse project, instructions will pop up that will show them how to sort photos.
- Students will sort the pictures, dividing them into two categories: "Yes, there is a hummingbird present." and "No, there is not a hummingbird present."
- Students will not need an account to access zooniverse, but they will need a device (preferably a computer or laptop) that has access to the internet in order to navigate to the project website.

Evaluation Activity: Journal reflection

- After sorting through the footage, students will write a short reflection in their journals about their experience sorting the wildlife camera footage and follow-up on their hypothesis.
- They will answer the questions: “How was your experience of collecting wildlife camera data?” and “After seeing some images of hummingbirds and noticing what time of day they were taken, do they still think their hypothesis is correct? Why or why not?”

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The Bio/Diversity Project
Lesson Title: Butterflies as Pollinators

Teacher: Lily and Grace
Grade Level: 9th
Lesson Length: 50 min

Based on Existing Lesson Plans: Teaching about the Magnificent Monarchs and The Great Monarch Migration Learning Activity

AZ Science Standard:	*HS.L4U1.27* ● Obtain, evaluate, and communicate evidence that describes how changes in frequency of inherited traits in a population can lead to biological diversity
Learning Objective:	● Students will be able to map the migration route of monarchs, including the areas they travel between and stops they make along the way. ● Students will be able to describe the threats to monarchs' migration patterns and how these threats affect their population. ● Students will be able to explain the importance of monarch migration and what we can do to help.
Scientist of the Week:	● Eduardo Rendón Salinas ● Monarch butterfly expert ● Manages the monarch butterfly monitoring program at World Wildlife Fund (WWF)-Mexico ● Studies and reports colony sizes ● Advocates to put monarch butterflies on the IUCN Red (Threatened Species) List to create nationwide policies that protect this species and their environment ● https://monarchnet.org/featured-scientists

Vocabulary	Materials
• Migration • Life cycle • Adaption • Deforestation	• Slideshow • Butterfly Mapping Handout (Class set: 105) • Colored pencils for a class of ~30 students • Life Cycle Wheel: - Scissors - Glue or tape - Brass fastener (105) - Print 105 copies: Life Cycle Wheel PDF

Seasonality: Any

Monsoons	*Autumn*	*Winter*	*Spring*	*Dry Summer*
July-Sept.	Oct.-Nov.	Dec.- Feb.	Mar.-Apr.	May-June

Guiding Questions:

- What are the key structural features that distinguish butterflies from moths, and how does this affect their methods of pollination?
- What are the varying hypotheses surrounding how the Monarch Butterfly finds the same overwintering site from generation to generation?
- What is the significance of the butterflies as mythical or ritual symbols in pre-Hispanic cultures?

Engagement/Introductory Activity: Butterfly Life Cycle Wheel Cutout

- How to Make a Life Cycle Wheel:
  1. Copy both of the Life Cycle Wheel templates (Base and Cover). The parts can be laminated or pasted on heavier paper to make them more durable.
  2. Copy the Butterfly Life Cycle Stages sheet.

3. Cut out the life cycle wheel base.
4. Cut out pictures of the egg, larva, chrysalis, and adult butterfly from the Butterfly Life Cycle Stages sheet.
5. Glue the life cycle pictures onto the sections of the wheelbase in order clockwise, beginning with eggs and ending with an adult butterfly.
6. Cut out the wheel cover. Be sure to cut out the window of the cover.
7. Place the cover over the wheel base. Push a brass paper fastener through the center of the cover and the wheelbase to connect the two. The life cycle wheel is now complete. There are several ways to use the life cycle wheel. You might have the student rotate the cover to a stage of the life cycle and tell you about that stage. You might instead use the wheel to show a student a stage of the life cycle and ask what comes before or after.

- Students will make a revolving wheel that models the phases of butterflies' life stages.
- Students will have 10 minutes to complete this activity because the circles and butterfly pictures will be pre-cut upon the start of class.

Exploratory Activity: Introducing Migration on the whiteboard

- Start the discussion by asking students to define migration.
- Migration is an example of an animal adaptation, a behavior passed down through generations that helps the species survive. Animals that migrate exhibit this behavior for different reasons—most often to avoid a changing climate, to look for food, or to reproduce.
- After peer-to-peer discussions, interns will ask students for examples of species that migrate, creating a class-generated list on the whiteboard.

Explain: Monarch Butterflies' Migration Routes: Pollinating Along The Way Lecture with aThink-Pair-Share Follow-Up.

- Using the provided slides as a guideline, explain to students the significance of the monarch migration. During the spring and summer months, there is a large population of monarchs dispersed throughout areas of the northern United States and southern Canada. As fall approaches, these monarchs set out on the nearly 3,000-mile journey to the forests of central Mexico that will provide them with shelter from the winter cold. The butterflies will hibernate in these forests for several months until the temperature indicates it is safe for them to emerge. Then they will begin the journey home, traveling north, stopping to reproduce along the way.
- What makes the migration pattern of monarchs so unique and fascinating is not only the vast distance covered, but the fact that it takes several generations of butterflies to complete the journey from start to finish in one year. This means that each butterfly is traveling a route that it has never seen before and that the butterfly completing the cycle by arriving back home is several generations beyond the original butterfly that began the journey. Describe to the students this migration route taken by many monarchs so they fully understand the concept. It may help to display your own map and refer to it while explaining.
- **First leg:** Fall is approaching, temperatures are dropping, and monarch butterflies throughout the northern United States and southern Canada are heading out on a long journey. This generation of butterflies is responsible for traveling all the way to the forests of the Monarch Butterfly Biosphere Reserve in Michoacán, Mexico, to hibernate in Mexico's warm climate and avoid the harsh cold of winter. Once their winter hibernation is over and temperatures indicate spring has arrived, typically by March, these butterflies will awake and begin the journey north.
- **Second leg:** As this generation of butterflies heads north, they will stop to eat and reproduce along the way, laying eggs along milkweed plants. This generation lives the longest, about seven or eight months, hence why they're referred to as the "super generation". After a few weeks of traveling north, these butterflies reach Texas and die, leaving a new generation to emerge from their eggs and continue the journey north.
- **Third leg:** This next generation of butterflies will continue to travel north for about four to five weeks, stopping in various states along the way to eat and lay eggs, before eventually dying. Their offspring will emerge and continue the journey from where their parent butterflies left off for approximately four to five

weeks before dying.

- **Fourth leg:** This pattern happens one or two more times, resulting in a fourth or fifth butterfly generation completing the last leg of the journey to areas of the northern United States and Canada where they rest and reproduce during the warm months. One of the most popular areas for monarchs during the summer is the grasslands of the Northern Great Plains, spanning Nebraska, North Dakota, South Dakota, Wyoming, and Montana in the United States, as well as Saskatchewan and Alberta in Canada. These grasslands provide ideal habitat for monarchs to feed and lay eggs.
- Emphasize to students the relevance of this monarch migration to people. Monarchs are pollinators, responsible for transporting pollen between flowering plants, fertilizing them. The plants then produce seeds and fruit, all of which humans use to make various food products. Without monarchs and other pollinators, a lot of the food we routinely depend on would not exist. It's important for monarchs to complete their migration cycle with the necessary habitat to reproduce and continue their role of pollinating.
- After the lecture, conduct a think-pair-share, asking which of the following migration spots they would like to visit: Michoacán, Mexico, Dallas, TX, Virginia Beach, VA, or Toronto, Canada.

Extension Activity/Questions: Migration Maps

- To better understand the geographical significance of the monarch's efforts and pollination routes, students will create maps that chart their migration pattern.
- Distribute the student map handout included in this activity, as well as coloring utensils, to each student.
- Now that they are familiar with the migration pattern of monarch butterflies, instruct students to be creative and incorporate the information to illustrate this route on their map. Their maps should include the following:
    - Michoacán, Mexico, the location of the Monarch Butterfly Biosphere Reserve and the place where many monarchs spend their winters
    - Migration directions: which way do monarch butterflies travel when it is too cold? Which way do they travel when it is too warm?
        - Arrows that show the direction monarch butterflies travel in the Fall
        - Arrows that show the direction monarch butterflies travel in the Spring
    - Summer breeding areas (most of northern U.S. and nearly all of Western U.S.- area is highlighted on example map)
    - A legend, including symbols to represent the directional flying routes, seasons, the monarchs themselves, etc.

Evaluation Activity: Journal Entry About Habitat Conservation Actions

- Inform students about the challenges monarch butterflies face due to habitat loss in their migratory routes across North America. Discuss how deforestation in Mexico and habitat conversion in the United States threaten these migration patterns by reducing the availability of milkweed, the primary food source for monarch caterpillars.
- Then, we will prompt students to open up a blank page in their journals, and list three specific actions that would support monarch butterfly habitats. Encourage students to work with their neighbors to share ideas, and inform them that it is okay to have similar answers to other classmates. Encourage them to think about actions such as planting native milkweed, reducing pesticide use, or educating others about monarch conservation. After writing their commitments, allow a few students to share their plans with the class, discussing how each action can make a positive impact on monarch populations. This activity combines reflection, creativity, and public speaking skills in a concise format.

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The Bio/Diversity Project

Lesson Title: Computer Lab - Hummingbird Data Analysis Pt. 1

Teacher: Grace and Lily
Grade Level: 9th
Lesson Length: 50

This lesson has been adapted from Pollinators - Hummingbirds and Our World in Data, Protected Areas

AZ Science Standard:	• U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.
Learning Objective:	• Students will be able to log into posit.cloud, a platform for using the coding language R, and execute code from a real-world data set. • Students will be able to explain how rows and columns organize data.
Scientist of the Week:	• Deja Perkins • Top STEM leader in North Carolina • Ph.D. student studying geospatial analytics • Perkins is currently investigating the relationship between income and patterns of data collection in urban areas • In 2020, she helped launch #BlackBirdersWeek, a social media movement that aims to highlight Black bird watchers, naturalists and outdoor enthusiasts •  https://cnr.ncsu.edu/news/2022/02/deja-perkins-recognized/

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Vocabulary	Materials
• Geospatial • Columns • Rows • Data Science	• Computer Lab Access • Computers • Posit.cloud accounts ○ Coding lesson (in posit.cloud, but this is a PDF version for reference) • Slideshow • Student journals and writing utensils

Seasonality: Any

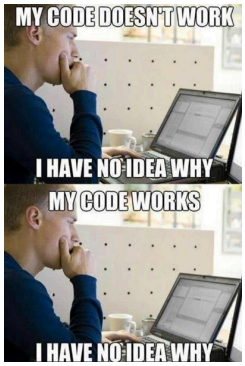
Monsoons	*Autumn*	*Winter*	*Spring*	*Dry Summer*
July-Sept.	Oct.-Nov.	Dec.- Feb.	Mar.-Apr.	May-June

Guiding Questions:

- How do scientists model and analyze data using R?
- What are the benefits of visualizing data in a computer?

Engagement/Introductory Activity:

- Present students with relatable and comical memes about the importance of being resilient and utilizing problem-solving skills while learning how to code for the first time.
- Students can ask questions about computer science, coding, and computer lab expectations during this time.
- Memes:



Exploratory Activity:

- Students will be able to model how scientists use computer science to analyze data and answer questions about the world.
- The three parts of Coding Lesson 1 are *Loading The Data*, *Viewing The Data*, and *Counting Hummingbird Sightings*.
- Students will learn to read R comments, run functions, and understand the difference between the Console, Environment, and Terminal in posit.cloud during this lesson.

Explain:

- Students will pair up in the computer lab. One of the group members will log into posit.cloud.

- Together, students will follow along to Coding Lesson 1. By the end of class, they will be able to explain how R organizes data with rows and columns and the time the most hummingbirds visited CHS.
- The three columns are labeled Image.number, Path.to.image.in.directory, and Time.stamp.
- Each row holds the above information about one hummingbird image.
- Using the head(), nrow(), and View() functions, students be able to answer the objectives.

Extension Activity/Questions:

- In this interactive discussion, students will dive into the concepts of rows and columns within data frames, specifically focusing on the 'hummingbird_times' dataset used in the R coding lesson. The aim is to understand the basics of data structures in R and the specific applications to our hummingbird sightings.
- Students are encouraged to bring forward any questions or curiosities about R, coding practices, or nuances of the dataset that weren't covered during the standard lesson.
- Additionally, this session will serve as a brainstorming platform for students to propose creative data uses. Ideas could range from predicting future hummingbird visitation patterns analyzing the impact of environmental changes on hummingbird behavior, to integrating the data with other datasets for broader ecological insights. This activity aims to inspire innovative thinking and foster a deeper connection between coding skills and environmental science.

Evaluation Activity:

- For this evaluation activity, students will do reflective journaling about what they learned from the coding lesson. This written exercise will prompt students to articulate their understanding of the data structure used in the lesson (rows and columns in the hummingbird_times dataset) and to reflect on the insights gained from analyzing the data.
- Journal prompts will include the following:
    - Describe what the rows and columns in the hummingbird_times dataset represent.
    - What does the number of rows in the hummingbird_times dataset tell us about the presence of hummingbirds at our school?

The R activity instructions and HTML is listed on the following pages:

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Posit Cloud Activity Instructions: Hummingbird Sightings Analysis HTML Link

Hummingbird Sightings Analysis

Welcome to our Hummingbird Analysis Project! We're going to find out what time of day hummingbirds like to visit our school campus. We'll use R, a programming language, to look at pictures taken by our wildlife cameras and see when we spotted hummingbirds.

Remember our research question: What time of day do hummingbirds most frequently visit the Catalina High School campus?

Part 1: Getting Started with R and Our Data

Step 1: Loading the Data

First, we need to load our data into R. This data is stored in a file called valid_timestamps.csv. You can find it at the bottom right of your screen, where you opened up this file. Each row in this file represents one picture of a hummingbird.

By running the code below, you are reading the data set with all the times hummingbirds were spotted with our cameras. This data came from your hard work sorting photos!

Run your code by pressing the green run button (little green arrow in the top right of the code chunk)!

```
{r}
# This is a comment. It shows up in green. You can also tell it's a comment by the "#" symbol that comes before the text.
# Comments are ways for us to take notes in our code, for ourselves or other people, without it talking to the computer.

hummingbird_times <- read.csv("valid_timestamps.csv")
```

Great! Now we have our data loaded, and we can look at it. See the hummingbird_times data frame in the top-right window of your screen.

Step 2: Viewing The Data

First, click where it says hummingbird_times in the top right portion of your screen. This should open the entire data set. Take a minute to scroll through and get an idea of what the data looks like.

Note: 24-hour time

Imagine a day as a big circle. Instead of splitting the circle into two halves (AM and PM), we use the whole circle for the day, starting at 00:00 right after midnight and counting all the way up to 23:59 right before the next midnight.

With the 24-hour clock, we don't need to say "AM" for the morning or "PM" for the afternoon. If it's 15:00, you know it's the afternoon because it's after 12:00, which is lunchtime. Note: 15:00 is equal to 3:00 PM. This time-counting method is called Military Time.

Discussion / Journal Entry: What do you think the rows and columns represent? What time of day did the most hummingbirds visit CHS?

Next, let's take a peek at our data using code. The head() function lets us look at the first 6 rows of our data. Run the code below to use the head() function!

{r}
head(hummingbird_times)

As we can see, our data is divided up into rows and columns.

Step 3: Counting Hummingbird Sightings

We can count how many times we saw hummingbirds by counting the number of rows in our data set, because each row is one sighting. If we use nrow(), it will tell us how many rows are in our data set!

{r}
nrow(hummingbird_times)

Discussion / Journal Entry: What does the number of rows in the hummingbird_times data set tell us about hummingbirds at our school?

COLLEGE OF SOCIAL & BEHAVIORAL SCIENCES
Women in Science & Engineering

The Bio/Diversity Project
Lesson Title: Pollinators in Urban Areas

Teachers: Grace and Lily
Grade Level: 9th
Lesson Length: 50 minutes

This lesson has been adapted from Planting for Pollinators, How to Create an Urban Garden in Small Spaces

AZ Science Standard:	• U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.
Learning Objective:	• Students will be able to list three ways urbanization impacted pollinators • Students will be able to explain one pollinator conservation strategy • Students will be able to draw and plan an urban garden
Scientist of the Week:	 **Dr. Alexandra Nicole Harmon-Threatt** Her interest in the environment started when she was in college, at the age of 25. She's led groundbreaking research on pollination biology, bees, and how pollinators interact with urban areas like cities. Works as an entomologist (studies insects) at the University of Illinois. She is passionate about providing the same opportunities to her female students, especially those of color, to increase the representation of women of color in academia and the natural sciences.

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Vocabulary	Materials
• Conservation • Habitat Loss • Ecosystem Diversity • Landscape	• Lesson Plan 6 • Poster boards or white construction paper • Pencils, color pencils, or markers • Plant and seed options booklet • Tucson news article

Seasonality: Any

Monsoons	*Autumn*	*Winter*	*Spring*	*Dry Summer*
July-Sept.	Oct.-Nov.	Dec.- Feb.	Mar.-Apr.	May-June

Guiding Questions:

- How has urbanization impacted pollinators?
- How can urban areas act as places of refuge for pollinators?
- How do pollinators contribute to the overall ecosystem diversity in urban areas?

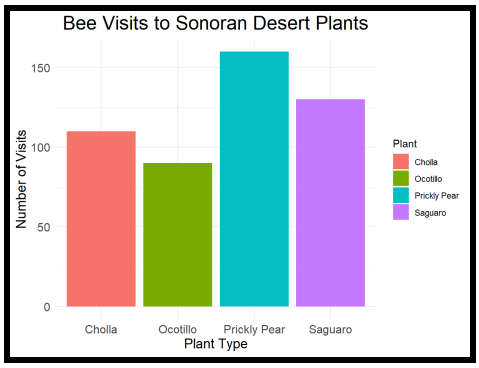
Engagement/Introductory Activity:

- Objective: Kickstart the lesson by engaging students with real-world issues affecting bees in Arizona, their importance to biodiversity, and how urban gardens can play a pivotal role in their preservation.
- Invite students to volunteer for a reading activity. Present them with quotes from the January 2024 local Tucson news article "Gardening helps protect threatened bees in Arizona." The quotes are carefully chosen to highlight the critical situation of bees in Arizona due to urban expansion and the practical steps individuals can take to mitigate these threats.
- Selected Quotes:
    - "Arizona is home to the second-most diverse bee population in the country … more than 1,300 native bee species reside in the state."
    - "[Bees in Arizona] tend to nest underground in abandoned burrows from other animals and dead or hollowed-out plants. Urban expansion limits their habitat options and puts more space between the bees and the water and food sources they need access to."
    - "People can attract native bees to their gardens and help them thrive by planting native [desert] wildflowers."
    - "To help the bees access water, people should create water stations outside their homes so bees can have reliable access to the water they need to cool down their homes."
- These quotes will help lead into today's lesson on urban gardens and their role in supporting pollinator populations.

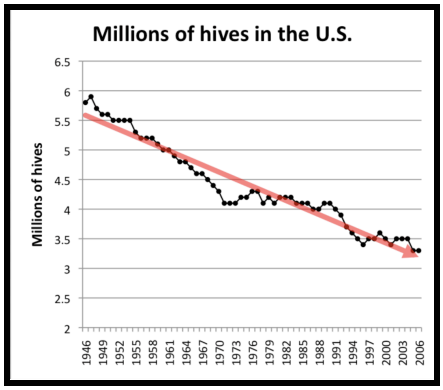
Exploratory Activity:

- Begin by explaining the concepts of a bar graph:
    - A bar graph is a type of graph that shows how many times something happens.
    - A bar graph helps us quickly see which amounts happen often and rarely.
    - Bar graphs make it easy to compare different groups or times.
    - We can see if most values are high, low, or in the middle.

- Then, show students an example of a bar graph with bee data:



- Students will be asked to answer questions about how they interpret the bar graph in a think/pair/share format:
  - ❖ About how many times did bees visit Saguaros?
  - ❖ Which plant did these bees like the most?
- Next, explain the concepts of a scatter plot:
  - ❖ A scatter plot is a type of graph that uses dots to show the relationship between two different things.
  - ❖ They help us understand how one thing is related to another. For example, does studying more lead to better test scores?
  - ❖ Scatter plots can reveal if there's a pattern or trend between the two things we're looking at, like an upward trend showing that as one thing increases, so does the other.
- Show students an example of a scatter plot:



- Discuss how the X and Y axis are related by saying, "As _?_goes up, _?_ goes (up or down)."

Explain:

- Students will watch the short YouTube video "How to Help Pollinators in Cities."
- https://youtu.be/JsypVU8VkS4?si=qdvznfytXpkUQIsV
- Afterward, they will participate in a Think, Pair, Share exercise to explain and share one place where they commonly see pollinators, such as bees, butterflies, and hummingbirds, and tell a neighbor why they think pollinators like to roam this area.

Extension Activity/Questions:

- ❖ Students will create an urban pollinator garden design on a poster board or piece of construction paper.
- ❖ Challenge students to think about how they would design one area of their school.
- ❖ They will consider what plants are native to Tucson and those pollinators like to visit by referring to the Plants and Seeds Booklet Plant and seed options booklet.
- ❖ In addition, they should consider:

- ➢ Space size and landscape
- ➢ The amount of sunlight the space receives
- ➢ Using vertical gardening techniques or raised beds to maximize the growing area
- ➢ Drip irrigation system, self-watering planters, feeders, houses, etc
- ➢ How humans interact with the space

- ❖ After learning several conservation strategies, students will design a fictional or personal space incorporating various conservation strategies and tools.
- ❖ Students can use colored pencils or markers to complete their posters.

Evaluation Activity:

- Think about it question: "What is one way you plan to help protect pollinators after leaving this class today?"
- Students will volunteer to share their answers to this question and takeaways with the class.

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The Bio/Diversity Project
Lesson Title: Coding Lesson #2

Teacher: Grace and Lily
Grade Level: 9th
Lesson Length: 50 minutes

This lesson has been adapted from: How can you use data visualization to enhance scientific communication?

AZ Science Standard:	• U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.
Learning Objective:	• Students will be able to use R to write code that creates a visualization of the wildlife camera footage we collected. • Students will be able to explain how data science contributes to science communication. • Students will be able to print their graphs to put on their posters next week.

Scientist of the Week:	• Student's Choice - 4 minute duration
	• Who is a scientist in your life that you want to showcase?
	• Scientist: someone who studies natural (physics, biology, chemistry) or social (politics, cultural, economics) sciences.
	• Nurse, teacher, chef, baker, gardener, researcher, zoo keeper, yourself, etc
	• In your journals write:
	  ○ Their name
	  ○ Your relationship
	  ○ Why you picked them
	  ○ A short description or story about their scientific work
	  ○ How their work made an impacted on you!
	• 
	• Conduct a Neighbor Share in which students will discuss with a table-mate who they picked, their scientist's background, and their work

Vocabulary	Materials
• Science communication • Scientist • Data visualization	• *Coding Lesson 2 Slides - Lesson 7* • *Coding lesson #2: Also in posit.cloud* • *Access to computers for coding*
Seasonality: Any	

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Monsoons July-Sept.	*Autumn* Oct.-Nov.	*Winter* Dec.- Feb.	*Spring* Mar.-Apr.	*Dry Summer* May-June

Guiding Questions:

- What are data visualizations?
- How can data visualizations help scientists share their research and findings?
- How can we create a data visualization on the computer?

Engagement/Introductory Activity:

- Students will come up with their own scientist of the week
- They will pick someone in their lives who they want to showcase. It could be someone who studies natural (physics, biology, chemistry) or social (politics, cultural, economics) sciences, like a nurse, teacher, chef, baker, gardener, researcher, zookeeper, or themselves.
- They will be given 4 minutes to write in their journals, with the following prompts:
    - Their name
    - Your relationship
    - Why you picked them
    - A short description or story about their scientific work
    - How their work made an impact on you!

Exploratory Activity:

- Students will raise their hands and share one type of data visualization with the class. The interns will write the class's extensive list on the whiteboard. Examples are bar plots, pie charts, timelines, tables, sketches, etc.
- Students will learn why data visualization matters and how we can use computer science to enhance our science communication skills by:
    - ❖ Presenting complex data in a more accessible, engaging, and persuasive way
    - ❖ Capturing people's attention
    - ❖ Identifying the important points quickly
    - ❖ Comparing and contrasting scenarios
    - ❖ Highlighting patterns
    - ❖ Evoking emotions

Explain:

- Teachers will briefly explain what data visualization is and why it matters before heading to the computer lab to create one!
    - Data science is the study of collecting, organizing, and analyzing large amounts of data to uncover helpful information and insights. It involves using computer programming and statistical techniques to understand patterns and trends in data, which helps people answer questions.

    - We can use data science and computers to enhance our science communication skills by:
        - ■ Presenting complex data in a more accessible, engaging, and persuasive way
        - ■ Capturing people's attention
        - ■ Identifying the important points quickly
        - ■ Comparing and contrasting scenarios
        - ■ Highlighting patterns
        - ■ Evoking emotions

Extension Activity/Questions:

- Students will follow along with the code in posit.cloud to create their histograms, plotting the occurrences of birds found at CHS at different times of day.

Coding lesson #2

What are we doing?

Our wildlife cameras were busy capturing birds coming and going from Catalina High School. Each time a bird is spotted, the camera records the time of the day. We've saved all these timestamps in a file named valid_timestamps.csv.

But here's the challenge: how do we find out the most popular times for bird visits?

With a few lines of R code, we can create visual graphs that show us exactly when our feathered friends prefer to say hello!

Setting Up Our Toolbox

Before we can dive into our data, we need to make sure we have the right tools. In the world of coding, these tools are called "packages," and they help us do special tasks without writing a lot of code ourselves. For our adventure, we'll need three packages. Install them by running the following code. **You only have to run this once.**

```{r}
install.packages("ggplot2")
install.packages("dplyr")
install.packages("readr")
```

Now that the packages are installed, load them in using the following code:

```{r}
library(ggplot2)
library(dplyr)
library(readr)
```

Reading the Bird Log

Our next step is to read in our data, like we did last lesson. It is saved in the **`valid_timestamps.csv`** file. We'll run this code:

```{r}
data <- read_csv("valid_timestamps.csv")
```

Preparing the Data

Now, we have a data set full of times, but we want to break it up into categories so it is easier to understand. We need to organize it! We'll create categories for the time of day and format the hours in a way that's easier to read.

Don't worry about understanding every detail of this code; just know it helps us get our data ready for graphing:

```{r}
prepare_time_data <- function(data, time_column) {
  data %>%
    mutate(
      Hour = factor(substr(!!sym(time_column), 1, 2), levels = sprintf("%02d", 0:23)),
      TimeOfDay = cut(as.numeric(Hour), breaks = c(-1, 6, 12, 18, 24), labels = c("Night", "Morning", "Afternoon",
"Evening"), include.lowest = TRUE),
      HourNum = as.numeric(Hour), # Temp column for AM/PM conversion
      HourAMPM = ifelse(HourNum == 0, "12 AM", ifelse(HourNum < 12, paste(HourNum, "AM"),
ifelse(HourNum == 12, "12 PM", paste(HourNum - 12, "PM")))),
      HourAMPM = factor(HourAMPM, levels = c("12 AM", paste(1:11, "AM"), "12 PM", paste(1:11, "PM")))
    ) %>%
    # Ensure 'TimeOfDay' is a factor with all four periods as levels
    mutate(TimeOfDay = factor(TimeOfDay, levels = c("Night", "Morning", "Afternoon", "Evening")))
}
data_prepared <- prepare_time_data(data, "Time.stamp")
```

Creating Our Graphs

With our data ready, it's time to reveal the secrets it holds. We're going to create three graphs:

1. **Visits by Hour**: This shows us how many birds were spotted during each hour of the day in 24-hour time.

2. **Visits by Time of Day**: This divides the day into four parts - Night, Morning, Afternoon, and Evening - to see when birds prefer to visit.

3. **Visits by Hour with AM/PM**: A closer look at the hours using AM and PM, which we are more familiar with!

Graph #1: Bird Visits By Hour

This graph shows us how many bird visits were recorded during each hour of the day. It helps us see which hours are the busiest and which are the quietest. Replace the title (where it says "Enter Descriptive Title Here!") with a descriptive title of what this graph is showing!

```{r}
ggplot(data_prepared, aes(x = Hour)) +
  geom_bar(fill = "skyblue", color = "black") +
  scale_x_discrete(drop = FALSE) +
  labs(title = "Enter Descriptive Title Here!", x = "Hour", y = "Frequency") +
  theme(axis.text.x = element_text(angle = 45, hjust = 1),
        plot.title = element_text(hjust = 0.5))
```

Graph #2: **Bird Visits by Time of Day**

This graph divides the day into four parts—Night, Morning, Afternoon, and Evening—to see when birds like to visit most.

```{r}
```

```
ggplot(data_prepared, aes(x = TimeOfDay)) +
  geom_bar(fill = "lightgreen", color = "black") +
  scale_x_discrete(drop = FALSE) +
  labs(title = "Bird Visits by Time of Day", x = "Time of Day", y = "Frequency") +
  theme(axis.text.x = element_text(angle = 45, hjust = 1),
        plot.title = element_text(hjust = 0.5))
```

Graph #3: **Bird Visits by Hour with AM/PM**

This graph offers a closer look at the day's hours, using the familiar AM/PM format to see when our feathered friends prefer to make their appearances.

```{r}
ggplot(data_prepared, aes(x = HourAMPM)) +
  geom_bar(fill = "coral", color = "black") +
  scale_x_discrete(drop = FALSE) +
  labs(title = "Bird Visits by Hour (AM/PM)", x = "Hour (AM/PM)", y = "Frequency") +
  theme(axis.text.x = element_text(angle = 45, hjust = 1),
        plot.title = element_text(hjust = 0.5))
```

Pick Your Favorite Graph

Think back to the three graphs we created together:

1. **Bird Visits by Hour**

2. **Bird Visits by Time of Day**

3. **Bird Visits by Hour (AM/PM)**

Which one did you like the most? Was it the detailed hourly breakdown, the broad view of the day's times, or the familiar AM/PM format?

Paste in Your Code

Now, take the code for your favorite graph and paste it here:

```{r}
# Paste your favorite graph's code here!


```

Bonus Activity: Customize Your Graph

It's time to add your personal touch. We can do this by changing the colors. Remember the part in the code that looks like **`fill = "skyblue"`** or **`fill = "lightgreen"`**? That's where you decide what color your bars will be!

Run the following code to see the LONG list of colors that R understands:

```{r}
colors()
```

More Bonus Customization Options

Feeling adventurous? Here are a few more ways you can customize your graph:

- **Outline Color**: Change the **`color = "black"`** part to another color like **`"grey"`** or **`"darkblue"`** to modify the outline color of your bars.

- **Title Style**: Customize your title further by adding **`face = "bold"`** or changing its color with **`color = "darkgreen"`** inside the **`plot.title = element_text()`** part.

- **Background Color**: Give your plot a background color with **`theme(plot.background = element_rect(fill = "lightgrey"))`**, replacing **`"lightgrey"`** with your desired background color.

Example of Full Customization

Here's how your code might look after some customization:

```{r}
ggplot(data_prepared, aes(x = Hour)) +
  geom_bar(fill = "plum", color = "darkblue") +
  scale_x_discrete(drop = FALSE) +
  labs(title = "Example Graph: Bird Visits by Hour", x = "Hour", y = "Frequency") +
  theme(axis.text.x = element_text(angle = 45, hjust = 1, color = "navy"),
        plot.title = element_text(hjust = 0.5, face = "bold", color = "darkgreen"),
        plot.background = element_rect(fill = "lightgrey"))
```

Evaluation Activity:

- Once students have completed their graphs and styled them to their liking, they will be asked to save their final project on posit.cloud.
- Teachers will log on to posit.cloud, access each student's project, and save the image they created for their final graph.
- Teachers will print out each student's work and bring it to their final class where they will incorporate their graph in a poster.

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The Bio/Diversity Project

Lesson Title: Final Lesson - Student Posters

Teacher: Grace and Lily
Grade Level: 9th
Lesson Length: 50 minutes

This lesson has been adapted from [Tips for Students: Creating and Presenting Research Posters]

AZ Science Standard:	• U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.
Learning Objective:	• Students will be able to create a poster that displays the findings of our hummingbird data • Students will be able to scientifically communicate their findings to peers
Scientist of the Week:	•  • Deborah Goldberg • Professor in the Department of Ecology and Evolutionary Biology at the University of Arizona • Conservation Ecologist • She researches how plants grow and interact together in the Sonoran desert • Goldberg works in the Tumamoc Hill research lab called the "Desert Laboratory" • Who has hiked Tumamoc Hill before?

Vocabulary	Materials
• Introduction ❖ Include our research question - "What time of day do birds most frequently visit Catalina High School?" ❖ Include your hypothesis • Methods ❖ Include 1-2 sentences: How did we collect our data? ❖ Include 1-2 sentences: How did we analyze our data?	• Poster boards • Markers • Colored pencils • Print-outs of student graphs • Glue • Lesson 8

❖ Include your graph, created in R ● Conclusion ❖ Include 1-2 sentences: What is the answer to our research question (above)? ❖ Include 1-2 sentences: Were your hypothesis correct?	

Seasonality: Any

Monsoons	*Autumn*	*Winter*	*Spring*	*Dry Summer*
July-Sept.	Oct.-Nov.	Dec.- Feb.	Mar.-Apr.	May-June

Guiding Questions:

- How did we collect our data?
- How did we analyze our data?
- What makes a good scientific poster?
- How do we talk about science to our friends and family?

Engagement/Introductory Activity:

- Discussion: Begin by engaging students in a brief discussion reviewing what we've done so far for our action project.
- Outline expectations for student posters and explain relevant vocabulary. The introduction tells the people reading your poster what it's about and what your scientific question is, the methods tell people how you answer your question, and the conclusion tells them the answer you found.
    - Introduction
        - Include our research question - "What time of day do birds most frequently visit Catalina High School?"
        - Include your hypothesis
    - Methods
        - Include 1-2 sentences: How did we collect our data?
        - Include 1-2 sentences: How did we analyze our data?
        - Include your graph, created in R
    - Conclusion
        - Include 1-2 sentences: What is the answer to our research question (above)?
        - Include 1-2 sentences: Was your hypothesis correct?

Exploratory Activity:

- Poster Draft
- Divide students into the groups they worked with to create their graphs.
- Instruct them to plan and design a poster on a scratch piece of paper.
- Include small sketches and explanations.
- Encourage them to think about what supplies/colors they will need and to practice what they will write on their final poster.
- Duration: 10 minutes

Explain:

- Poster creation
- Using their rough draft, students will create posters with an introduction, methods, and a conclusion

section.
- Students will glue their printed R graphs onto the board.
- They will follow the guidelines listed above to accomplish this task.
- Emphasize the importance of clear presentation and accurate representation of data.
- Duration: 20-minutes

Extension Activity/Questions:
- Gallery walk
- Once posters are completed, the class will showcase their work via a gallery walk.
- Each group will put their poster on a desk and go around the room reading everyone's work.
- Encourage students to ask questions and engage in discussions about the various hypotheses and data presented!
- Duration: 10-minutes

Evaluation Activity:
- Class vote: After the gallery walk, facilitate a class vote on the favorite poster by writing the creator's name on a slip of paper.
- Students cannot vote for themselves.
- Encourage students to vote based on:
    - Clarity
    - Creativity
    - How they chose to explain the project
- Offer the winning team a prize, like candy!
    - Since this lesson is our last class, we will have an extra wrap-up activity to reflect on this semester's work:
    - Students will think about their favorite lesson, activity, or fact they learned from our time together and share their takeaways and perspectives on pollinators now with neighbors.