Natural Selection Unit

Lesson 6: A Finch Argument

Grade: 9–10 General Biology

Length of lesson: 95 minutes

Placement of lesson: Lesson 6 of 6

Unit Overarching Goal

Populations of organisms change over time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

Unit Central Question

What causes populations of organisms to change over time?

Lesson 6 Main Learning Goal

The factors of natural selection that explain the changes in one population are generalizable and can be used to explainchanges in other populations.

Lesson Focus Question

What causes populations of organisms to change over time?

Ideal student response

The medium ground finch population on the Galápagos Island of Daphne Major changed due to natural selection. The drought that occurred on the island in 1977 drastically decreased the amount of available food for the medium ground finch population. Finches with larger beaks were better able to compete for food by their ability to expose and eat seedsthat were encased in hard, thorny seed pods. Finches with smaller beaks were not as successful in accessing seeds encased in these hard seed pods. Consequently, medium ground finches with larger beaks were much more likely to survive, reproduce, and pass on the larger beak trait to their offspring.

Science Content Storyline

The medium ground finch population on the Galápagos Island of Daphne Major changed due to natural selection. The drought that occurred on the island in 1977 drastically decreased the amount of available food for the medium ground finch population. Finches with larger beaks were better able to compete for food by their ability to expose and eat seedsthat were encased in hard, thorny seed pods. Finches with smaller beaks were not as successful in accessing seeds encased in these hard seed pods. Consequently, medium ground finches with larger beaks were much more likely to survive, reproduce, and pass on the larger beak trait to their offspring.

Materials

- Evidence statement cards
- Argument Tool (partially completed)
- sticky notes (2-3 per student)
- Videoclip: Beak of the Finch
- Teacher graph set printed in color

Advance Preparation

- Make copies of the Argument Tool, one per student.
- Make copies of the evidence statement cards, one per team of students

<table>
<tr><th>Time (min)</th><th>Phase of Lesson</th><th>How the science content storyline develops</th></tr>
<tr><td rowspan="2">10</td><td>Revisit the Unit Central Question: What causes populations of organisms to change over time?</td><td rowspan="2">More individuals are born than can surviveand reproduce.
All individuals in a population have the same traits, but there are different versions of the trait in different individualsin the population.
Among individuals in a population, there iscompetition for limited resources. This competition could be for food, habitat, or mates.
Some of the differences in a trait will helpan individual survive longer and/or produce more offspring.</td></tr>
<tr><td>Lesson Focus Question: What causes populations of organisms to change over time?</td></tr>
<tr><td>65</td><td>Studies of Galapagos Islands and Ground Finches on Daphne Major
<u>Activity Setup</u>
Students are introduced to a new phenomenon that concerns changes that occurred to a population of ground finches after a severe drought.
<u>Activity</u>
Students analyze data and information to construct a scientific argument that makes a claim about what caused the population of finches to change.
Students engage in argumentation by using an Argument Tool.
<u>Activity Follow-up</u>
Students analyze and critique other students’ scientific arguments.</td><td>Competition for food can affect how many organisms within a population survive and reproduce.
Selection pressures can favor a certain trait variation.
A favorable trait variation may help an organism survive and reproduce.
If over time a certain selection pressure continues, a favorable trait can become more prevalent in the population.
Acquired traits cannot be inherited.</td></tr>
<tr><td>15</td><td>Summary and Link to Next Class Period: Teacher and students summarize the lesson and links to the post assessment.</td><td></td></tr>
</table>

Lesson 5: Explaining Changes in Loberg Lake Stickleback

Phase of Lesson: *Revisit the Unit Central Question and Lesson Focus Question*

Main Learning Goal: The factors of natural selection that explain the changes in one population are generalizableand can be used to explain changes in other populations.

Focus Question: What causes populations of organisms to change over time?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms thatare better able to survive and reproduce in that environment.

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Time: 10 Minutes

STeLLA Strategies

- Strategy 1: Ask questions to elicit student ideas and predictions
- Strategy 2: Ask questions to probe student ideas and predictions
- Strategy B: Set the purpose with a focus question
- Strategy G: Link Science ideas to other science ideas

Science Ideas

- More individuals are born than can survive and reproduce.
- All individuals in a population have the same traits, but there are different versions of the trait in different individuals in the population.
- Among individuals in a population, there is competition for limited resources. This competition could be for food, habitat, or mate.
- Some of the differences in a trait will help an individual survive longer and/or produce more offspring.
- Relationships in data can be causal orcorrelational.
- Not all evidence is relevant to the question.
- When using real data, all information that iswanted or needed is not always available.
- Field research often requires data collectionover long periods of time.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- Natural selection leads to perfection.
- Natural selection and evolution are equivalent terms.

Lesson 6: A Finch Argument

Introduction

You have completed several lessons to help you understand how the population of stickleback in Loberg Lake changed. In this lesson, you will have a chance to see if the ideas you have learned apply to another population of organisms.

Process and Procedure

1. The focus question for today's lesson is the unit central question that was introduced to you in Lesson 1: **"What causes populations of organisms to change over time?"** Reread your response to this question in Lesson 1. How would you answer this question now? In the space below, describe how your ideas have changed over the course of the last five lessons.

Focus on Student Thinking

- Following is an example dialogue among teacher and students:
    - S1: My response would now include the idea that there are differences in traits.
    - T: And why do you think that idea is important to add? **(Probe)**
    - S1: Hmm, I guess it's one of the factors that make up natural selection.
    - T: [pointing to ideas posted in the room] That seems consistent with our ideas about natural selection. Who can add on to S1's idea that differences or variation in traits is an important idea? S2. **(Elicit)**
    - S2: That idea is important because the environment can favor one type of trait variation over another.
    - T: Say more. **(Probe)**
    - S2: Well, if an organism, like the stickleback fish in our story, has a trait variation that is favored by the environment, that fish will survive and pass on that trait to its baby fish.
    - T: So, if a fish had the no-armor trait, it would most certainly survive and reproduce? **(Challenge)**
    - S2: I guess I never thought about that. Can I have some time to think about that?
    - T: Sure. (short pause)
    - S2: Just because a fish has the trait, it does not mean that the fish will survive. Like with the fish simulation, some of the fish without spines and armor still died because they could not get any food.
- Take advantage of an opportunity to highlight the idea that the focus here is changes in populations over time, meaning multiple generations, rather than changes in the size of

Implementation	Notes
Link to Prior Learning and Forecast ● Remind students that for the last five lessons, they have been thinking, talking, and writing about what caused the changes to the stickleback population in Loberg Lake. They learned that Darwin's idea of natural selection can account for the changes. However, what they don't know ishow generalizable the four factors are to other living populations. Does natural selection account for changes in populations other than the stickleback population in Loberg Lake or the snails studied by Pascoal and others? *Introduce the Lesson Focus Question* ● **STEP 1:** Reintroduce the unit central question. The unit central question and the lesson focus question are the same: "What causes populations to change over time?" Ask students to reread their response to this question, which can be found in Lesson 1, step 1. They should think about how they would answer this question now and then describe how their ideas have changed over the course of the last five lessons. Tell them that they have spent several lessons considering if natural selection can account for the changes with the stickleback, but in order to answer this unit question, theyneed to have an understanding of whether the factors of natural selection can apply to other populations. ● Ask for students to share how their ideas have changed from their initialresponse to the unit central question in Lesson 1. ● Use probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3)as students are sharing their ideas. Use these types of questions to have students emphasize the four factors of natural selection and how these factors can influence change in a population of organisms. Refer to ***Focus on Student Thinking*** in the SE key for example of questions to this step. ● Because these factors relate to the science concepts students will be identifying when using the Argument Tool, write the ideas related to the four factors of natural selection on the board, on a piece of chart paper, or use the sentence strips from Lesson 5. ● Let students know that they will want to refer to four factors as they begin to think about a new population scenario. The scenario they will be focusing on in today's lesson examines changes that occurred to a population of birds on an island in the Pacific Ocean. This island is part of the Galápagos archipelago, or chain of islands.	

Lesson 5: Explaining Changes in Loberg Lake Stickleback

Phase of Lesson: *Finches in a Drought—Activity Setup*

Main Learning Goal: The factors of natural selection that explain the changes in one population are generalizableand can be used to explain changes in other populations.

Focus Question: What causes populations of organisms to change over time?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms thatare better able to survive and reproduce in that environment.

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Time: 10 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions

Science Ideas

- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A favorable trait variation *may* help an organism survive and reproduce.
- If over time a certain selection pressure continues,a favorable trait can become more prevalent in the population.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- Natural selection leads to perfection.
- Natural selection and evolution are equivalent terms.

Studies of Galapagos Islands and Ground Finches on Daphne Major

2. Read the following to learn more about another population of organisms that has changed over time. Be prepared to use ideas from the reading about what changes occurred in this population of medium ground finches and explain what caused the changes.

Finches in the Galápagos Islands

For over 40 years beginning in 1973, Peter and Rosemary Grant conducted extensive studies of the living and nonliving components of the ecosystem on Daphne Major, a small island that is part of the Galápagos Islands. The Galápagos Islands are dry places, receiving on average 25 cm (10 in) of rainfall a year. But in 1977, the Galápagos Island of Daphne Major received nearly zero rainfall—only 24 mm, less than 1 inch. Using tweezers and nets, scientists on the island recorded how the number of seeds, insects, and cacti on the island declined sharply as organisms struggled to grow and survive without enough water. Later in 1983, the island experienced an El Nino effect and received 10 times more rain than normal. The scientists continued to study the environment through this period, gathering similar information about number of seeds, insects, and cacti. They found dense growth of vines that covered many cacti and provided habitat for insects.

The Grants caught, banded, and measured many species of finches. They counted their numbers and measured their mass, beak length, and mating habits. They tracked some individual finches throughout their lifetimes. For many individuals, they were able to determine if the individual mated or not each year.

STOP **Stop and Think**

Why would scientists record the data listed? Why would they gather data over so many years?

There are many species of finches on the island. These finches vary in size from 10 to 20 cm, weigh between 8 and 38 grams, and are dull colored. A male attracts a female through song and they interact based on song and appearance. Together they raise a brood of chicks. Although different species of finches eat different foods, small, soft seeds are favored by several species of finches on the island, including the medium ground finch.

The population of medium ground finches changed dramatically while the Grants were studying Daphne Major. How did the population change and what caused the population to change? To answer these questions, you will examine different data sets and, using your knowledge of how populations change over time generate, and evaluate two possible scientific explanations.

STOP **Stop and Think**

Thinking about the characteristics of ecosystems in general, why might the population of medium ground finches have changed so much?

Focus on Student Thinking

- Following is an example dialogue among teacher and students:
  - S1: I think that scientists collect data so they can study populations over time.
  - T: And why do you think studying populations over time is so important? (Probe)
  - S1: Hmm, I guess it's so they can see changes in populations.
  - T: Who can add on to S1's idea? S2? (Elicit)
  - S2: They can see things like how the environment changes and how the birds change.
  - T: Say more. (Probe)

Implementation	Notes
Activity Setup ● **STEP 2:** Let students know the scenario they will read about is a real case, much like the stickleback case. However, in this scenario, they will be learning about changes that occurred to a population of medium ground finches. The scenario is divided into three separate sections with questions after the first two passages in the reading (SE L6-2). Each question needs to be answered before they begin reading the next section. ● Remind students that after reading the scenario and answering the questions, they should have a solid understanding of *what* happened to the ground finch population and should begin thinking about *how* this might have happened. ● Have students read each passage and answer the accompanying questions. Preferably, this activity should be done individually. However, it can be completed in pairs to support reading abilities of all students in the class. ● As students are reading and answering the questions, circulate among them and ask probe questions (STeLLA Strategy 2) to clarify their thinking and the timeline of events. ○ Why would scientists record the data listed? Why would they gather data over so many years? Scientists would gather this data for years to see what happens to populations over time. The Galápagos Islands are an interesting place to study populations. ○ Thinking about the characteristics of ecosystems in general, why might the population of medium ground finches have changed so much? The factors of natural selection are at work on Daphne Major. The environment put selective pressure on some variations of traits and the proportion of particular variations of traits in the population changed over time. ● When students are done reading the scenario, ask them to share what happened to the ground finch population on Daphne Major and what mighthave happened to cause the population to change. Students should refer tothe reading as they share. The purpose is to ensure that students accurately*understand* the flow of events and the changes that occurred to the finch population. Additionally, ask one or two students about how these changes might have occurred and what evidence they would need to support such a claim. ● Refer to the slides that include maps of the Galápagos Islands, an image of the ground finch, and an image of the hard caltrop seedpod. Refer to these images as students are sharing what they learned about this phenomenon. Refer to ***Focus on Student Thinking*** in the SE key for example of questions to this step.	

Lesson 5: Explaining Changes in Loberg Lake Stickleback

Phase of Lesson: *Finches in a Drought—Activity*

Main Learning Goal: The factors of natural selection that explain the changes in one population are generalizableand can be used to explain changes in other populations.

Focus Question: What causes populations of organisms to change over time?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms thatare better able to survive and reproduce in that environment.

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Time: 40 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy 7: Engage students in constructing explanations and arguments
- ❖ Strategy 8: Engage students in using and applying new science ideas in a variety of ways and contexts

Science Ideas

- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A favorable trait variation *may* help an organism survive and reproduce.
- If over time a certain selection pressure continues,a favorable trait can become more prevalent in the population.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- Natural selection leads to perfection.
- Natural selection and evolution are equivalent terms.

Teacher Note: After leading a discussion based on the Stop and Think question, share the brief 5-minute clip excerpted from HHMI's BioInteractive Video, The Beak of the Finch, to help students get a sense of the Galápagos Islands, including Daphne Major, and the Grants' work. Have students return to the answers to the Stop and Think questions and add to their answers.

https://www.biointeractive.org/classroom-resources/origin-species-beak-finch

Timestamps: 01:12–04:40 and 05:59–07:19

3. To study the finch populations, scientists took a sample of birds from the area. This means that they caught, banded, and measured some of the birds in the area over a period of years. The question they were trying to answer was: What caused the population of medium ground finches on Daphne Major to change over time?

   With your team, choose the figures you will analyze and place a check mark in the first column of Table 1 for those you choose. Be prepared to justify why you selected some figures and did not select other figures.

   To analyze your assigned graph(s), follow the steps below.

   a. Identify changes, trends, or differences in your selected graphs or table.
   b. Write the words "What I see" or "WIS". Then write a short comment to describe the change, trend, or difference that you noticed. Draw an arrow from each statement to the change, trend, or difference you wrote about. You should create one to three WIS statements for each of your chosen figures.
   c. Also record your WIS statement or statements in the third column of table 1.
   d. After you study each figure, go back and begin to add a "What it means" or WIM statement under each "What I see" or WIS statement. The WIM statement will help you interpret the change, trend, or difference you see. To help you write the WIM statements, use information from previous lessons, the reading about the Galápagos Islands, your chosen figures, and the video clip. Be prepared to share where you obtained your information (e.g., previous lessons, the reading, other figures, or video).

Chosen	Figure number	What I see statement(s)	What it means statement(s)
	Figure 1: Population size of the medium ground finch between 1975 and 1978.	The size of the population of medium, ground finches decreased between 1976 and 1977 from a high of 1400 in early 1976 to a low of 200 in late 1977. H	This decrease was likely due to a drought on Daphne Major.
	Figure 2: Survival rate of adult medium ground finches between 1976 and 1993.	The survival rate of adult medium ground finches decreased to approximately 40-45 percent during the years 1976-1977. The survival rate of the finches dropped again to about 55 percent between 1984 and 1985. J	This decrease was likely due to reduced rainfall or drought on Daphne Major.
	Figure 3: Rainfall per year between 1973 and 1991	Rainfall per year between 1973 and 1991 includes peaks at 1983, 1987 and 1997 that correspond to years with more than normal rainfall. B	The increased rainfall may have been due to the El Nino effect.
	Figure 4: Survival rate of juvenile medium ground finches between 1976 and 1993	The percent of surviving juvenile medium ground finches was low (10 or less) from 1983-1993. D	The rates of survival may correspond directly to amount of rainfall and availability of smaller seeds with low rates of survival due to low rainfall

Implementation	Notes
Activity ● You may choose to have students follow the instruction in the SE or you may choose an alternative approach to help students make sense of the 10 figures provided in the activity. Option 1 follows the steps in the SE. Option 2 involves posting the figures around the room on chart paper as represented in the photos on later pages. **Regardless of which option you choose, you will need to carefully analyze each figure yourself to make sense of the data students will analyze.** ● **STEP 3 <u>OPTION 1</u>:** Have students work in small groups to do this step. Let them know that in step 3 they will be studying data related to the medium ground finch population on Daphne Major. Most of the data represented in the 10 figures were collected by the Grants. Emphasize that their job is to first make observations of the data and then, after they made all the observations they can, discuss what those observations mean. Just like in Lesson 2, they will be using the Identify and Interpret strategy to help them make sense of the figures. ● **STEP 3 <u>OPTION 2</u>**: Post 10 charts around the room. Each chart includes an 8 ½ X 11 copy of the figure (see photos). Have students work in small groups to analyze the figures. Assign the analysis of each figure to one group of students. Keep in mind that figure 10 is the most difficult to analyze. Since each class marks up the charts and the figures, you would need a set of charts for each class period. Each group should use the following process. Be sure to use probe and challenge questions to help students analyze their figure. 1. Complete the WIS step in the process for their assigned figure first. 2. All students should review the WIS statements for all figures, ***so they are better prepared to write WIM statements for their figure. Encourage students to ask questions of the authors of the WIS statements for other figures. They may also see additional WIS statements that could be added.*** 3. Each group should return to their chart and complete the WIM step for each WIS statement. 4. Each group should summarize and record the role/purpose for each figure in explaining either WHAT changed over time or WHAT caused the change over time or that the figure doesn’t relate to the change over time of the medium ground finch population on Daphne Major. 5. All students should review the charts for each figure and provide feedback on sticky notes. 6. Have them return to their chart, consider feedback, and revise as needed. ● Regardless of which option you choose, support the analysis process by asking appropriate probe (STeLLA Strategy 2) and challenge (STeLLA Strategy 3) questions to students. The last thing students do is record their ideas for each figure in the table (SE L6 – 4). **Use the provided card set if you think it’s helpful**.	

Table 1. Figures and Summary

Chosen	Figure number	What I see statement(s)	What it means statement(s)
	Figure 5: Number of large ground finch pairs by year 1983 through 2012.	Between 1983 and 1993 the number of large ground finch pairs was 12 or less. The number stayed between 5 and 30 from 1994 and 2009 and then increased to 50 pairs between 2010-2012. F	This data is not relevant to the scientific question.
	Figure 6: Medium ground finch offspring beak depth in 1976	The most common beak depth size for medium ground finch offspring in 1976 was 8.8 mm. I	Due to lower rainfall amounts and lower availability of small seeds, the medium finches with larger beaks were better able to compete for food, survive, and reproduce thus passing on the trait of slightly larger beaks.
	Figure 7: Medium ground finch offspring beak depth in 1978	The most common beak depth size for medium ground finch offspring in 1978 was 9.8 mm. A	The medium ground finches that survived and reproduced had slightly larger beaks and passed on that trait to their offspring.
	Figure 8: Seed abundance on Daphne Major between 1975 and 1978	Seed abundance increased to 150 g/m2 in mid-1976. It then deceased substantially to 25 g/m2 by the end of 1977. C	Lower rainfall likely caused there to be lower seed abundance while higher rainfall increases seed abundance.
	Figure 9: Seed size by year between 1976 and 1991	From 1976 through 1981 large seeds were more abundant than small seeds. From 1983 through 1991, small seeds were much more abundant than large seeds. E	Lower rainfall likely caused there to be lower amounts of the small seeds preferred by medium ground finches to be produced.
	Figure 10: Sparrow beak depth of offspring, biological parents, and foster parents	The slope of the line comparing foster parents and offspring in -0.18 and the slope of the line comparing biological parents and offspring is 0.98. G	Beak depth in sparrows is an inherited trait rather than a trait determined by the environment.

Implementation	Notes

Figure 1: Population size of the medium ground finch between 1975 and 1978.

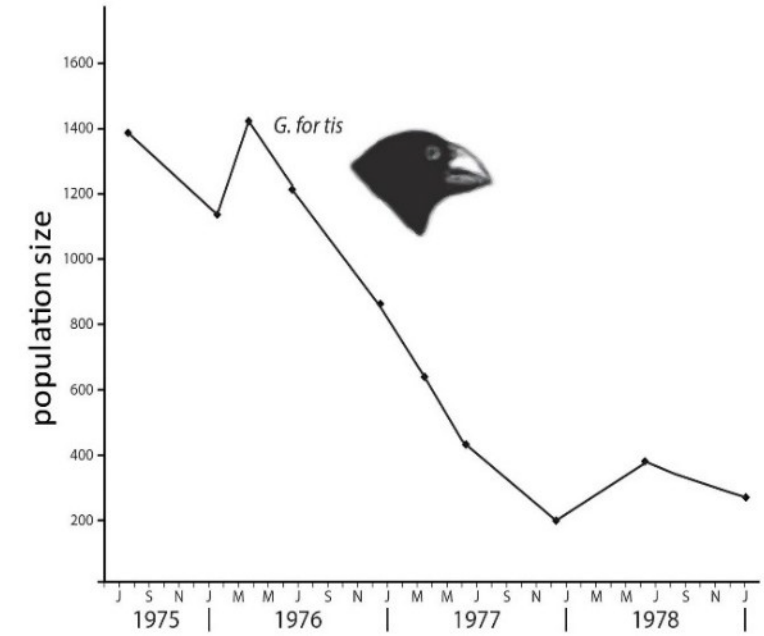
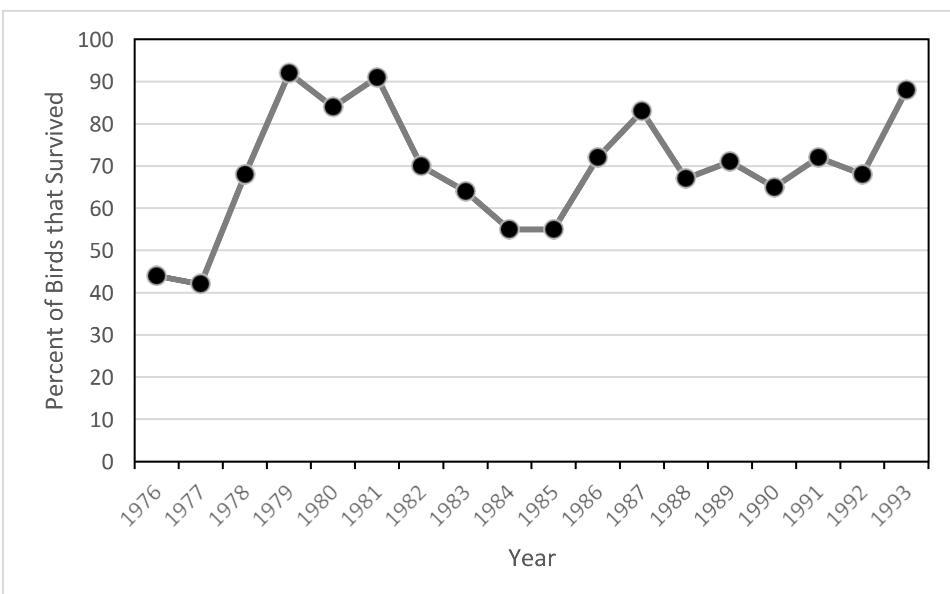


Figure 2: Survival rate of adult medium ground finches between 1976 and 1993.



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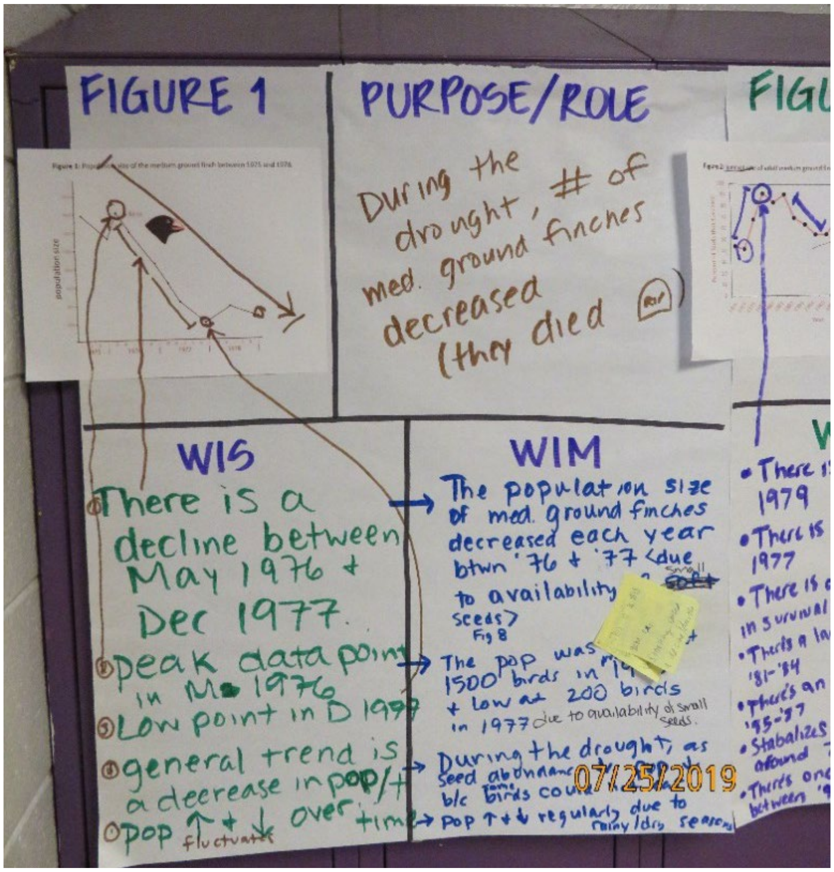
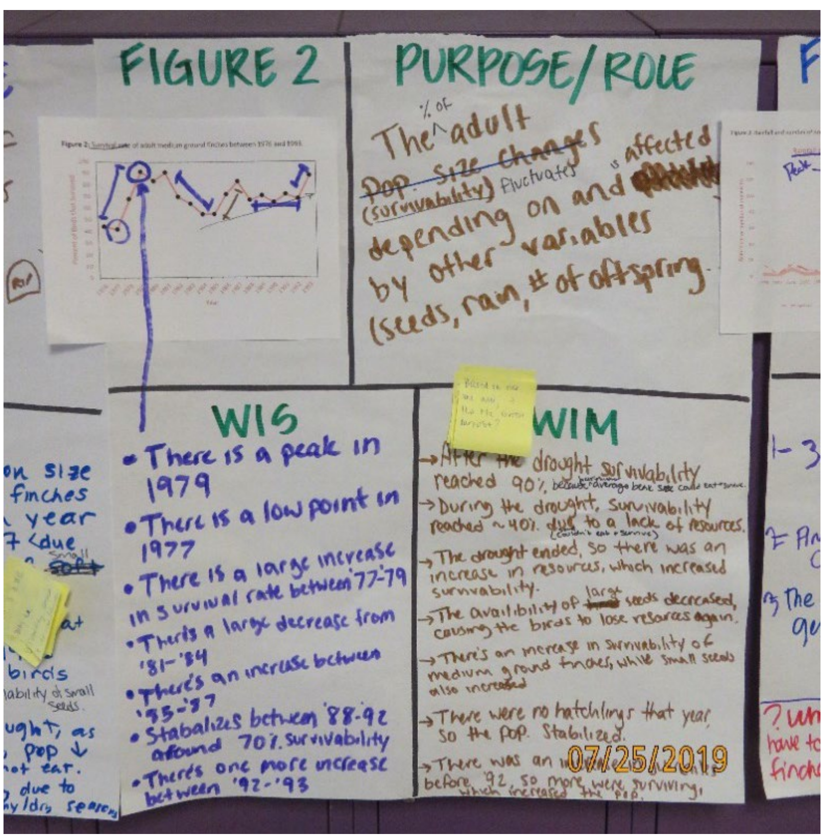
 	

Figure 3. Rainfall and number of organisms by year 1976 through 1991.

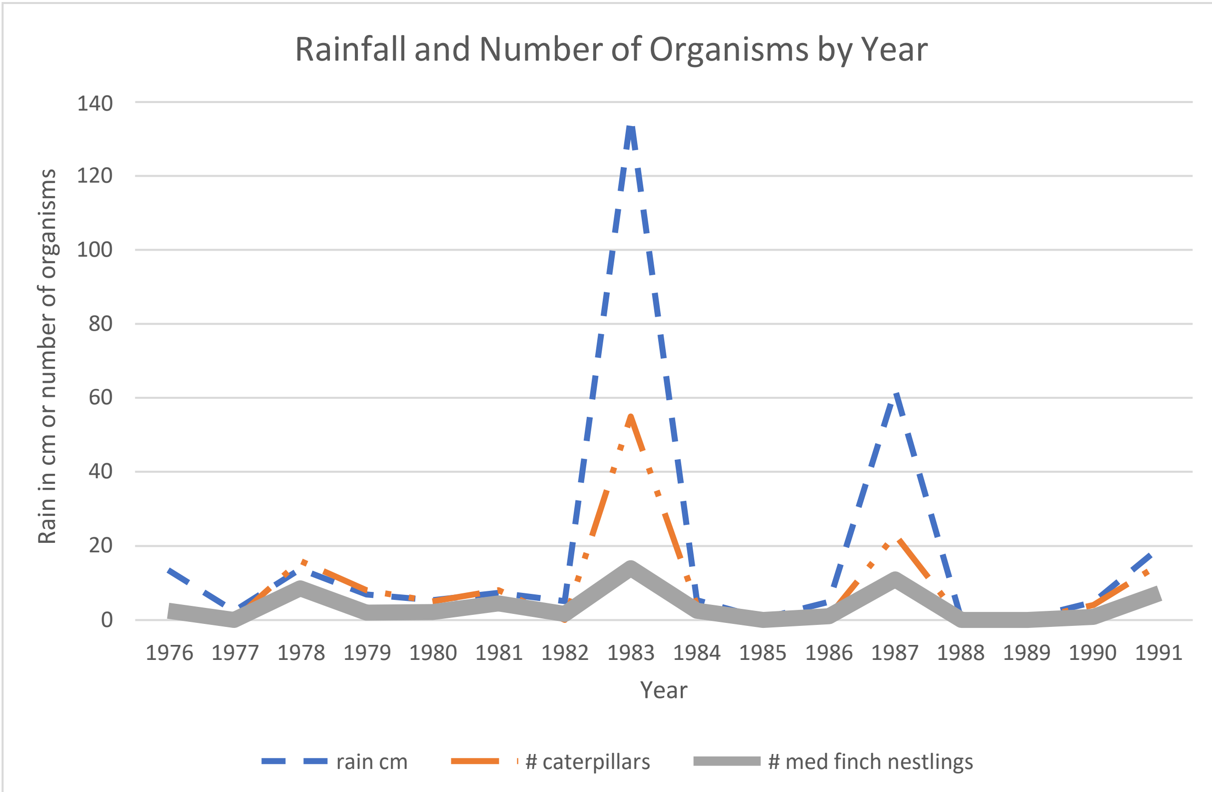
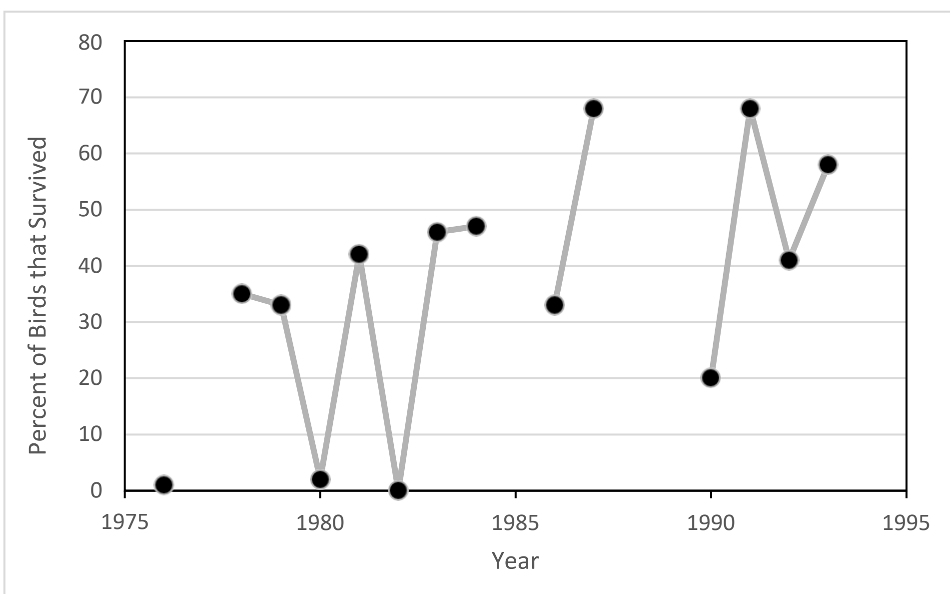


Figure 4: Survival rate of juvenile medium ground finches between 1976 and 1993. *Note that on this graph, the gaps in the line show that data were not collected in theyears where the line is not continuous.*



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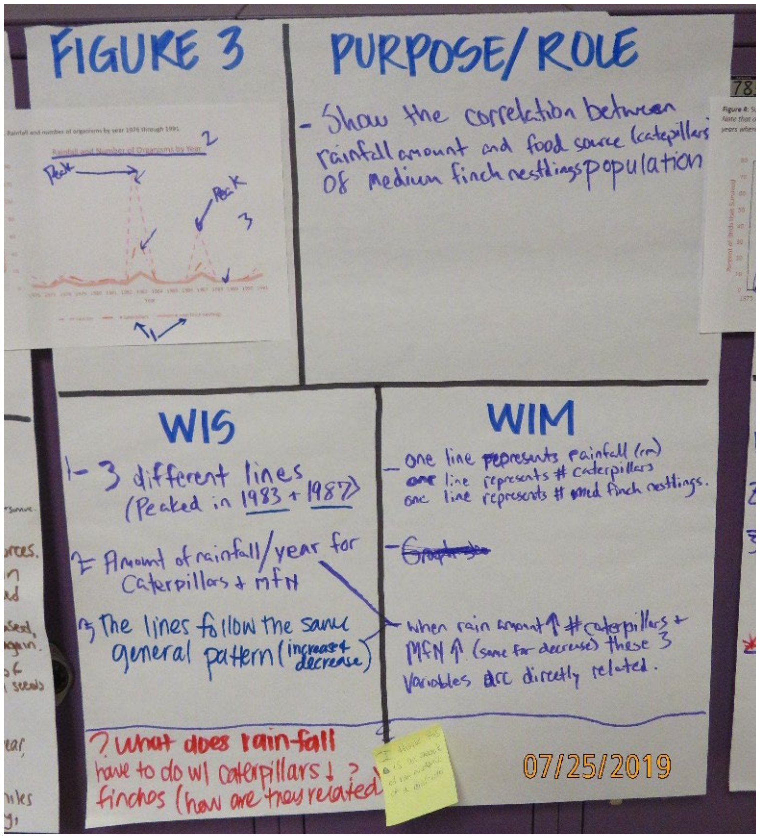
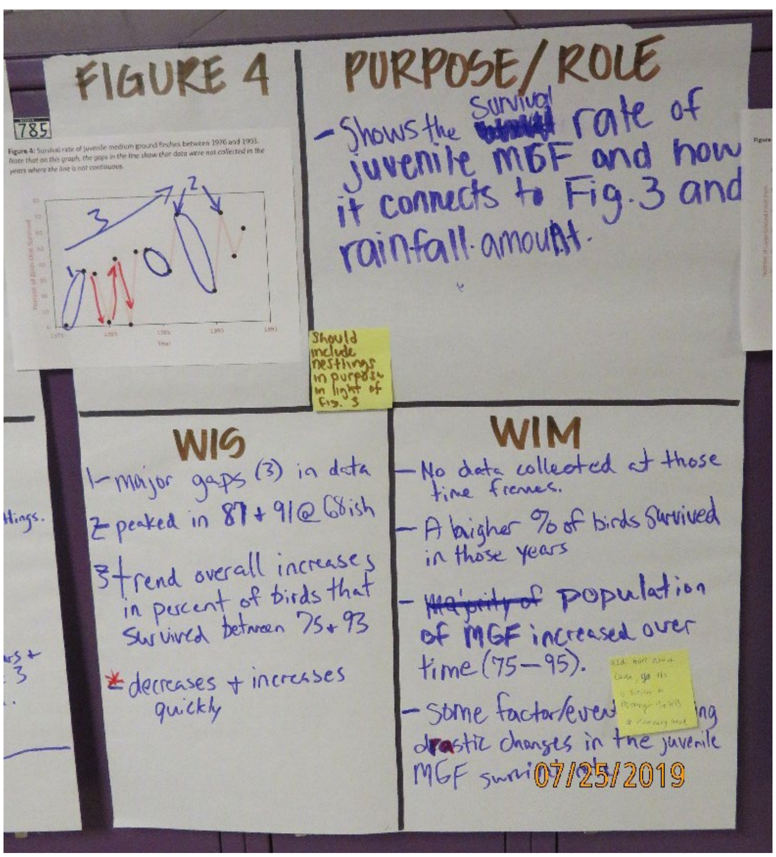
 	

Figure 5: Number of large ground finch pairs by year 1983 through 2012.

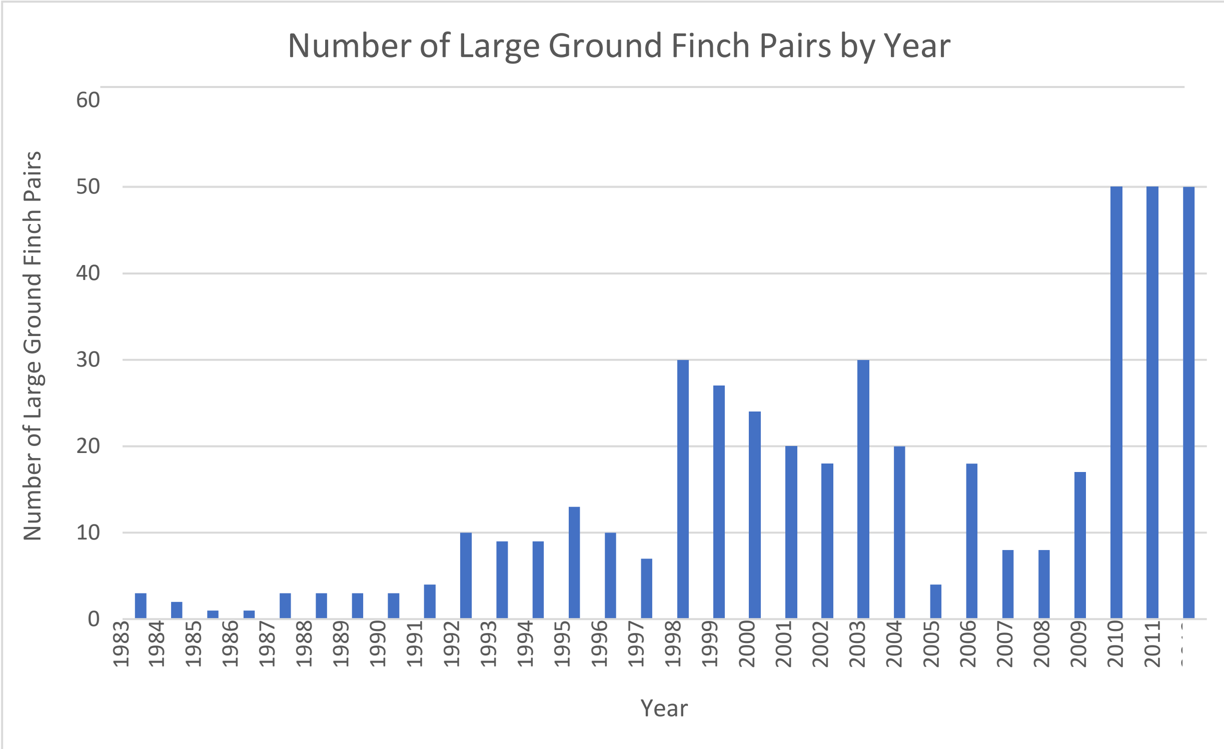
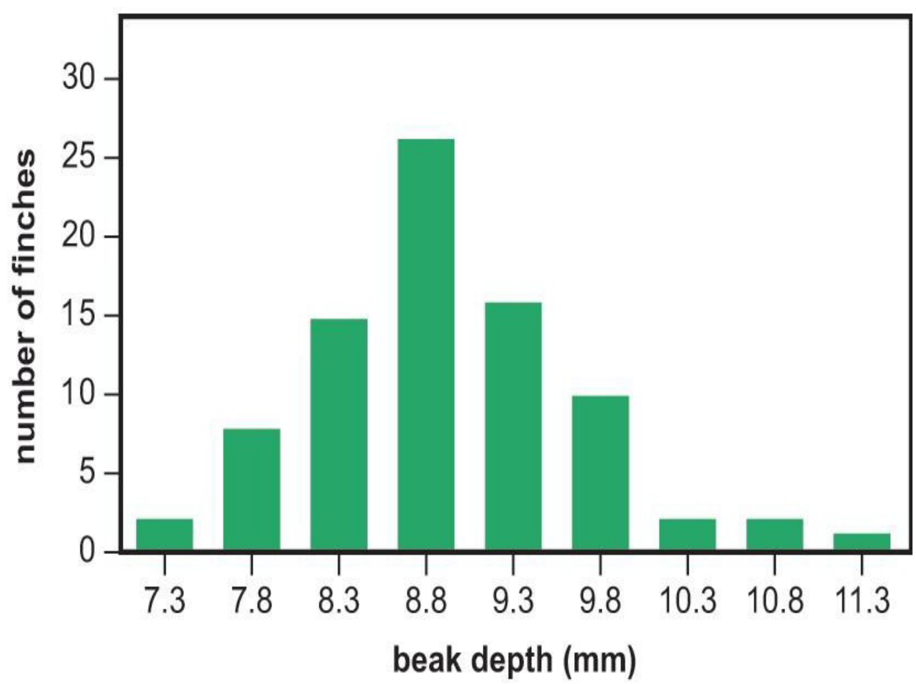
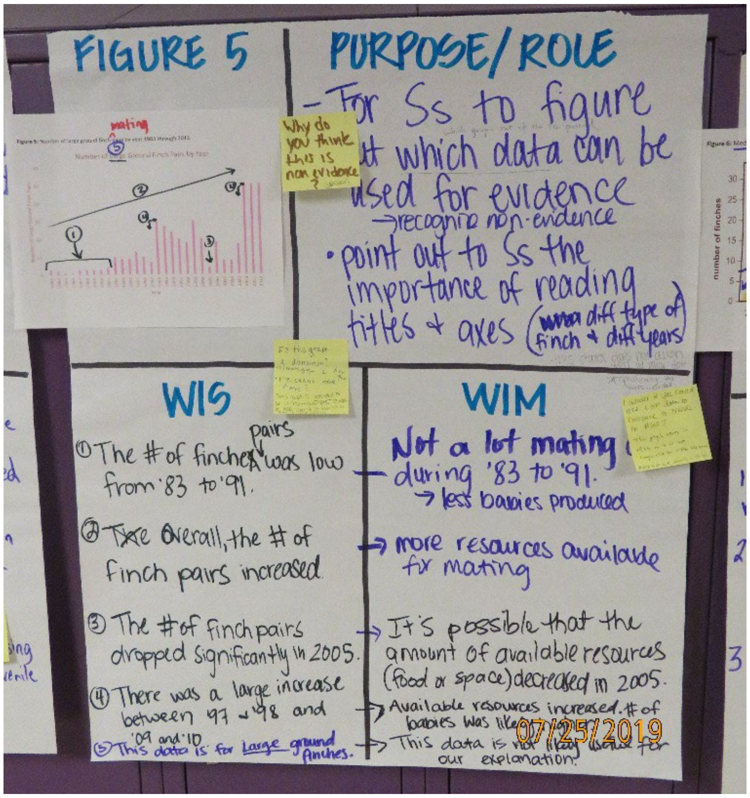


Figure 6: Medium ground finch offspring beak depth in 1976.



Implementation | **Notes**



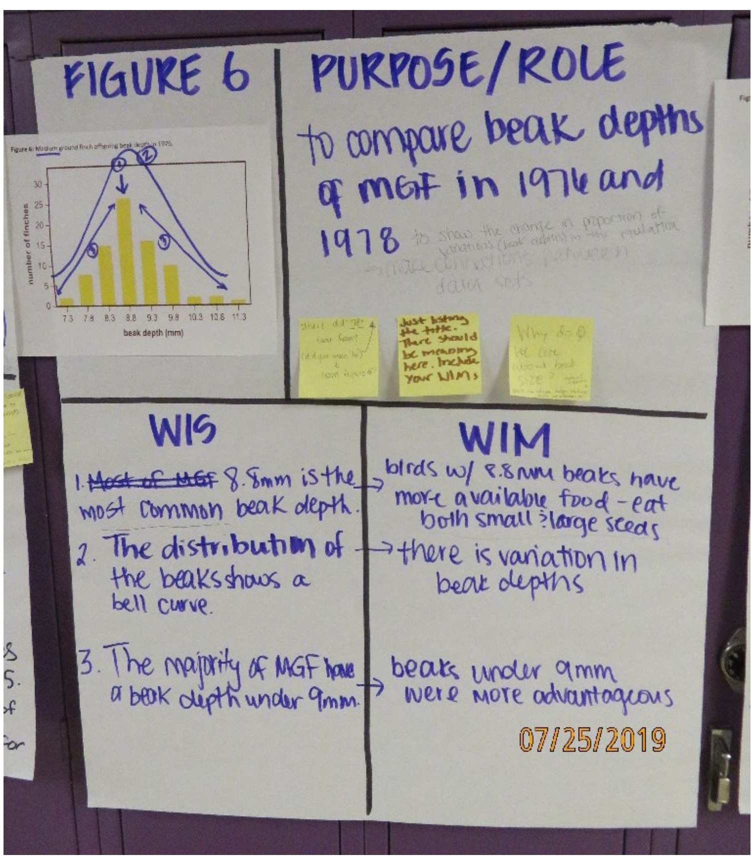


Figure 7: Medium ground finch offspring beak depth in 1978.

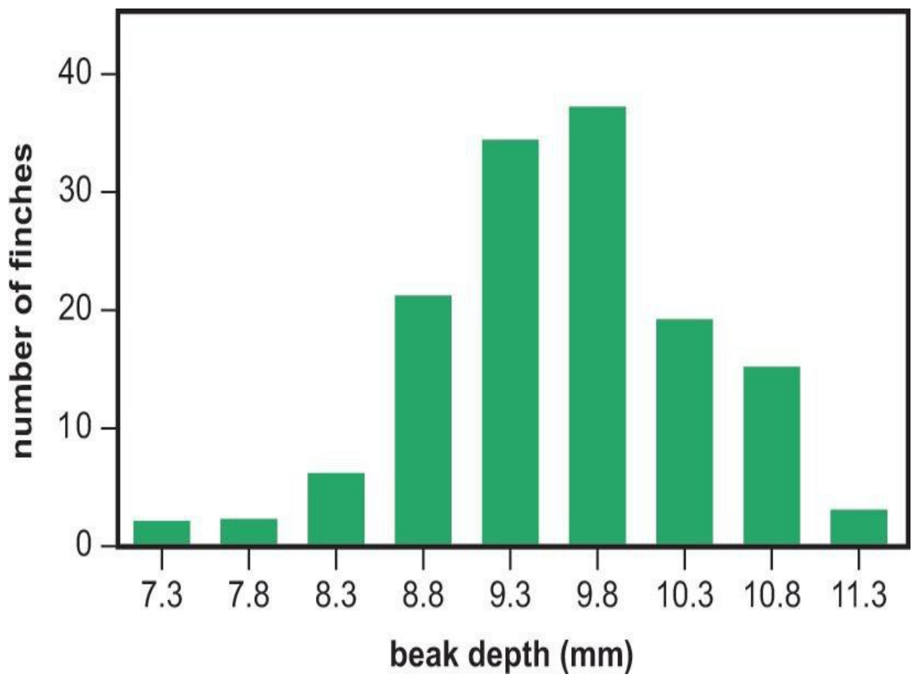
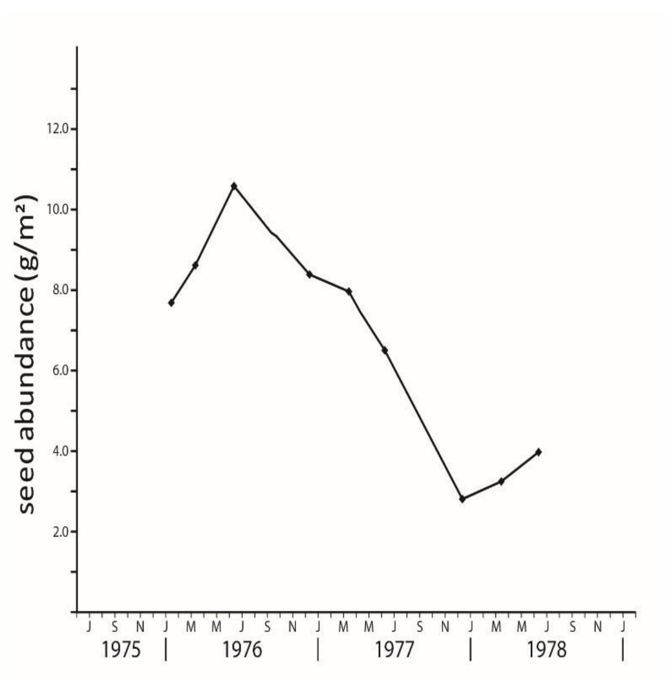
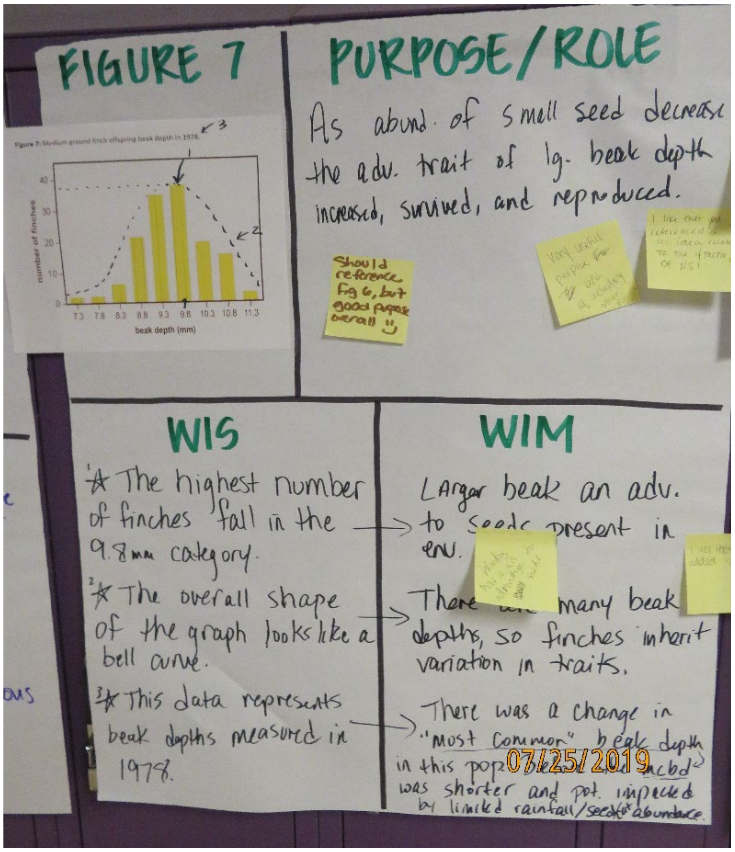


Figure 8: Seed abundance on Daphne Major between 1975 and 1978.



Implementation	Notes



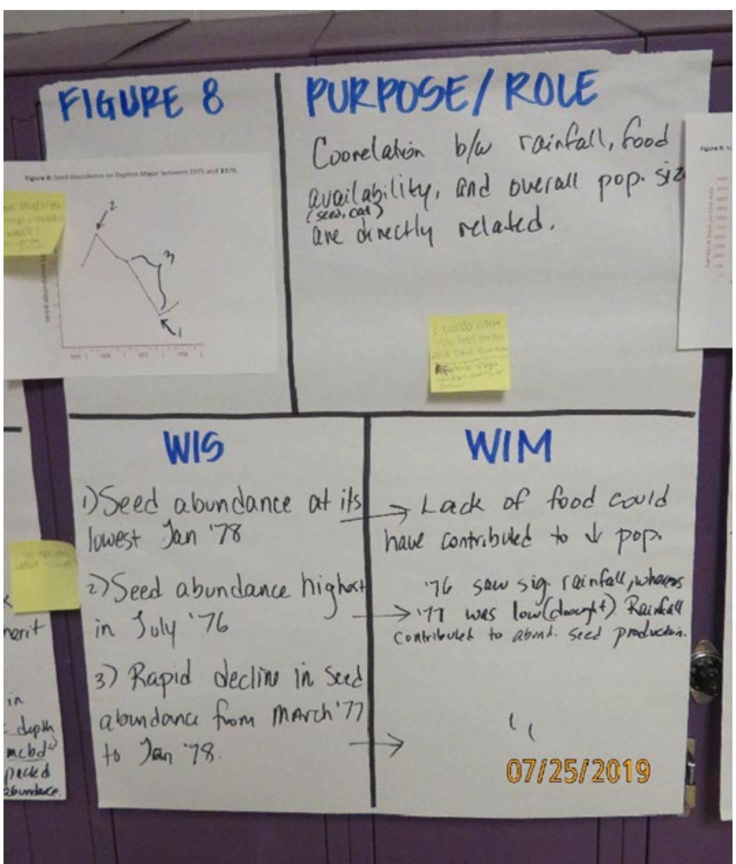


Figure 9: Number of large and small seeds per unit area by year 1976 through 1991.

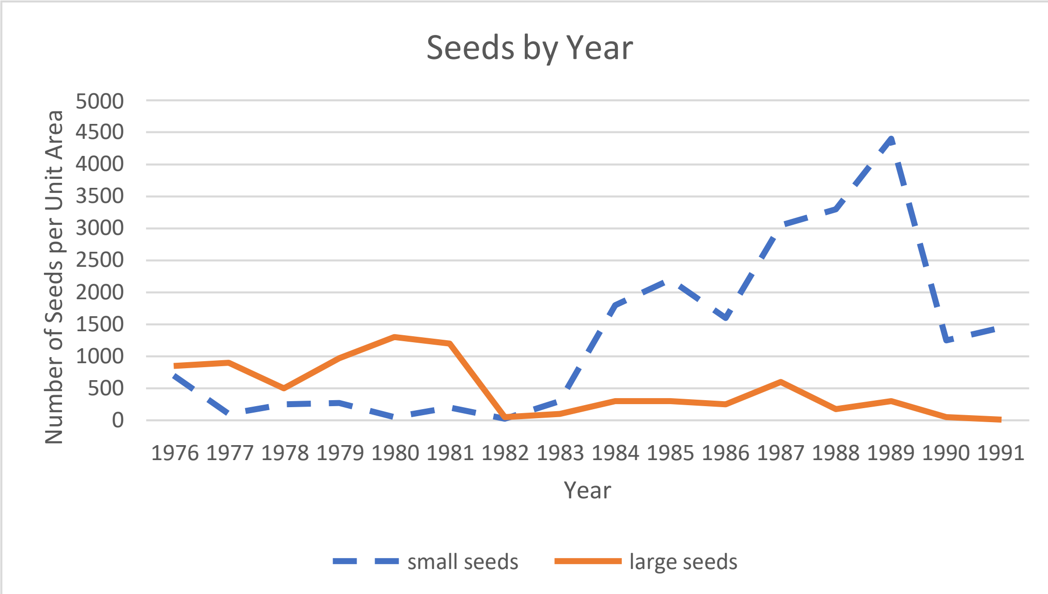


Figure 10: Sparrow beak depth of offspring, biological parents, and foster parents from sparrow egg switch experiment

	Foster parent/offspring (26 families)		**Biological parent/offspring (23 families)**	
Trait	**Slope**	**Standard Error**	**Slope**	**Standard Error**
Beak length	-0.06	0.43	0.37	0.19
Beak depth	-0.18	0.35	0.98	0.22
Beak width	-0.09	0.20	0.56	0.21

Sparrow egg switch experiment

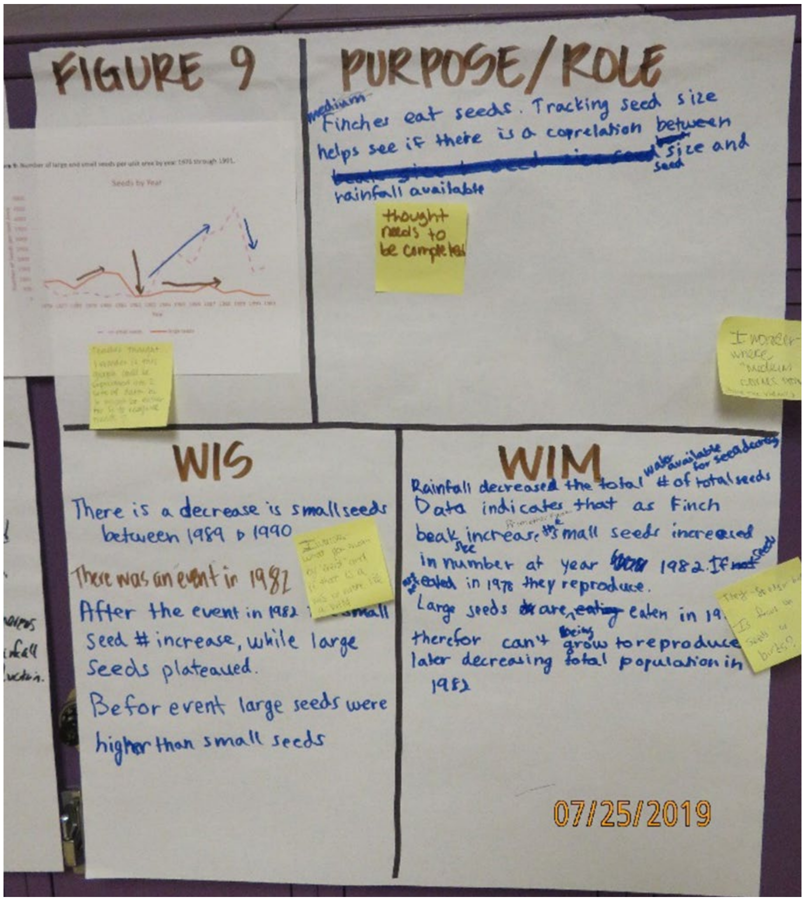
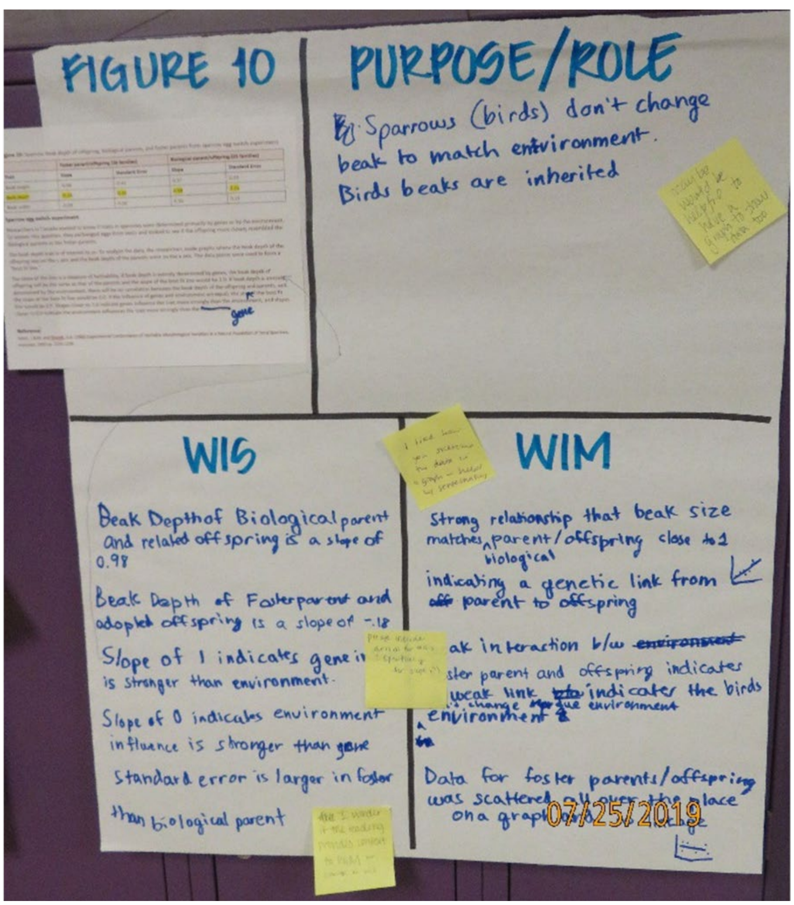
Researchers in Canada wanted to know if traits in sparrows were determined primarily by genes or by the environment. To answer this question, they exchanged eggs from nests and looked to see if the offspring more closely resembled the biological parents or the foster parents.

The beak depth trait is of interest to us. To analyze the data, the researchers made graphs where the beak depth of the offspring was on the y axis and the beak depth of the parents was on the x axis. The data points were used to form a "best fit line."

The slope of the line is a measure of heritability. If beak depth is entirely determined by genes, the beak depth of offspring will be the same as that of the parents and the slope of the best fit line would be 1.0. If beak depth is entirely determined by the environment, there will be no correlation between the beak depth of the offspring and parents, and the slope of the best fit line would be 0.0. Slopes closer to 1.0 indicate genes influence the trait more strongly than the environment and slopes closer to 0.0 indicate the environment influences the trait more strongly than genes.

Reference

Smith, J.N.M. and Dhondt, A.A. (1980) Experimental Conformation of Heritable Morphological Variation in a Natural Population of Song Sparrows, *Evolution*, 34(6) pp. 1155-1158.

Implementation	Notes
 	

4. You and your team will develop a scientific argument using the information and evidence you've gathered so far to help you answer the question: What is the best explanation for why the medium ground finch population on Daphne Major changed over time?

   Developing a scientific argument involves alternative claims or full scientific explanations that answer a scientific question. Developing a scientific argument requires the evaluation of each alternative claim by analyzing the quality and relevance of the evidence and reasoning used to support the claim and determining how well each claim answers the questions. A scientific argument includes two main parts: 1) a complete explanation that answers the question and provides a critique of the evidence and 2) a rebuttal. A rebuttal provides justification for why the alternative claim, evidence, and/or reasoning is insufficient, irrelevant, or inaccurate.

   Your teacher will provide a partially completed argument. The handout will include the question to be answered and two alternative claims. You will:

   a. consider the scientific question you are investigating.
   b. consider two possible claims that answer the question.
   c. add evidence that supports each claim. The sources of evidence include the summary statements you recorded in table 1 for selected figures, the Galápagos Island reading, and/or the videoclip excerpted from the Beak of the Finch.
   d. critique the quality of the evidence.

5. Think about the analysis of each figure you completed in step 3. For each WIS statement, decide whether it supports (or is consistent with) claim A, claim B, or both and list it in the appropriate box on the tool. If a WIS statement doesn't support either claim, leave it out.

Claim A Drought conditions led to a change in food availability that gave medium ground finches with big beaks a survival and reproductive advantage.	**Claim B** Drought conditions caused medium ground finches to increase their beak size in order to adapt to a change in the food supply so they could better survive.
The evidence (WIS statement) that supports this claim is … • The size of the population of medium ground finches decreased between 1976 and 1977 from a high of 1400 in early 1976 to a low of 200 in late 1977. (H) • The survival rate of adult medium ground finches decreased to approximately 40-45 percent during the years 1976-1977. The survival rate of the finches dropped again to about 55 percent between 1984 and 1985. (J) • The graph showing rainfall per year between 1973 and 2012 includes peaks at 1983, 1987, and 1997 that correspond to years with more than normal rainfall. (B) • The percent of surviving juvenile medium ground finches was low (10 or less) from 1983 -1994. It increased to 20-30 pairs between 1998-2004. There was a large increase to 50 pairs during 2010- 2012. (D) • The most common beak size for a medium ground finch in 1976 was 8.8 mm. (I)	**The evidence (WIS statement) that supports this claim is …** • The size of the population of medium ground finches decreased between 1976 and 1977 from a high of 1400 in early 1976 to a low of 200 in late 1977. (H) • The survival rate of adult medium ground finches decreased to approximately 40-45 percent during the years 1976-1977. The survival rate of the finches dropped again to about 55 percent between 1984 and 1985. (J) • The graph showing rainfall per year between 1973 and 2012 includes peaks at 1983, 1987, and 1997 that correspond to years with more than normal rainfall. (B) • The percent of surviving juvenile medium ground finches was low (10 or less) from 1983 - 1994. It increased to 20-30 pairs between 1998- 2004. There was a large increase to 50 pairs during 2010-2012. (D) • Seed abundance increased to 150 g/m2 in mid-1976. It then deceased substantially to 25 g/m2 by the end of 1977. (C)

Implementation	Notes
STEPS 4–5: Once students have completed step 3, have the small groups move on to step 4. Give the students some time to synthesize (STeLLA Strategy 9) the information and data they found out about the finch population so they can begin to formulate some ideas of what caused the population of finches that survived the drought to change. - Ask students to share ideas of what they think caused the population of finches to change. The focus of this sharing should be stated in cause-and-effect-type language and supported by evidence from the reading and graphs. Make the ideas that students share visible to all, either by charting the ideas or by having each group write an idea on a sentence strip. Post these in the room. - Examples could include the following: - The drought caused the population of finches to have bigger beaks because these birds could eat the hard seeds better. - Competition for food caused the changes in the finch population. Because there was less food, those finches that could not compete very well died. - The change to bigger beaks could have been caused by female birds favoring males with larger beaks. Since all the seeds that were left were hard, the female birds wanted to have babies with bigger beaks, so they mated only with males that had big beaks. - Bigger beaks were selected for by nature. - All the birds with small beaks died because they could not crack open the hard seedpods. - In some years, predators killed many of the baby birds. - <u>This should not be an evaluation of ideas</u>. Rather, the purpose of this share is to get different ideas out in a public space and prime students for using the Argument Tool. Use elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) as needed to reveal as many student ideas as possible during this time. However, refrain from the use of challenge questions (STeLLA Strategy 3) at this step.	

Claim A	Claim B
Drought conditions led to a change in food availability that gave medium ground finches with big beaks a survival and reproductive advantage.	Drought conditions caused medium ground finches to increase their beak size in order to adapt to a change in the food supply so they could better survive.
• The most common beak size for a medium ground finch in 1978 was 9.8 mm. (A) • Seed abundance increased to 150 g/m2 in mid- 1976. It then deceased substantially to 25 g/m2 by the end of 1977. (C) • From 1976 through 1981 large seeds were more abundant than small seeds. From 1983 through 1991, small seeds were much more abundant than large seeds. (E) • The comparison of beak depth between offspring and biological parents gives a line with slope of about .98 (nearly 1.0) while the comparison of beak depth between offspring and foster parents gives a line with slope of about .18 (closer to 0.0). (G)	• From 1976 through 1981 large seeds were more abundant than small seeds. From 1983 through 1991, small seeds were much more abundant than large seeds. (E)
Critique Critique the quality and strength of the evidence that supports this claim. • This claim has more evidence to support it. • This evidence better explains the change in beak depth of medium ground finches between 1976 and 1978. • This claim is consistent with Darwin's ideas about natural selection because beak depth is shown to be a heritable characteristic based on the egg swapping experiment.	Critique Critique the quality and strength of the evidence that supports this claim. • This claim has less evidence to support it. • If this claim was correct, then the data would show an immediate change in beak depth in 1976 rather than a change requiring two years.

Implementation	Notes

6. Work with members of your team and decide which claim, A or B, you think is best supported by evidence and scientific reasoning. Using the criteria listed below, write a scientific argument that includes:

   in the Scientific Argument box,

   - the scientific question,
   - the claim that best answers the question,
   - relevant evidence and reasoning that supports your claim,
   - scientific reasoning that critiques

   the evidence, and in the Rebuttal box,

   - a rebuttal that refutes the other claim.

   Part of your team should write the scientific argument. The other part of your team should write the rebuttal. Once you have completed your argument, move on to step 7.

Part 1: Scientific Explanation and Critique of the Evidence The scientific question to be answered is, "What caused the population of medium ground finches on Daphne Major to change?" The claim that best answers this question is Claim A, *Drought conditions led to a change in food availability that gave medium ground finches with big beaks a survival advantage.* This claim is supported by evidence of a drought in 1977 when rainfall was near zero (Figure 3). This year also coincided with a change in the food supply for medium ground finches. Before the drought, small and large seeds were present in approximately equal amounts. However, after the drought small seeds were hard to come by and large seeds became the primary food source (Figure 9). Birds with deeper beaks are better able to eat large seeds. This means that natural selection would favor medium ground finches with larger, deeper beaks. Evidence that natural selection was at work can be found by comparing the average beak depth of medium ground finches before and after the drought. Before the drought in 1976 the most common beak depth for a medium ground finch was 8.8 mm. (Figure 6). After the drought in 1978, the most common beak depth for a medium ground finch was 9.8 mm. (Figure 7). This increase in beak depth is consistent with the prediction that drought conditions that made large seeds more available would favor birds with larger beaks in the next generation. The final piece of evidence that supports the claim is the conclusion that beak depth is a heritable trait in sparrows (Figure 10). Although this data comes from another bird species, finches and sparrows are closely related so it is probable that the results from sparrows would also apply to finches.
Part 2: Rebuttal I did not argue for the Claim B, Drought conditions caused medium ground finches to increase their beak size in order to adapt to a change in the food supply because it implies that the medium ground finches were somehow aware that they needed to have larger beaks with which to eat the more plentiful large seeds. Birds (and other animals) cannot will themselves to change a heritable trait. Such changes are not made within a single generation but may take place in the next generation or after many future generations. The fact that the average beak size increased only after a new generation was produced is not consistent with the claim that medium ground finches adapted to change in food supply within the timeframe of their own lives.

Implementation	Notes
● **STEP 6:** Since students have not yet worked with the Argument Tool, they should be led by the teacher through each part of the process. However, let students know that they will still work in their small groups as they progress through each part. The process used to complete step 6 is repetitive and is found below. Be sure to use probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) as students are sharing ideas. ● The purpose of step 6 is for students to identify science ideas/concepts and the types of evidence they will need to construct a scientific argument related to the question they are investigating. ● Use the following process as students work through each part of step 6. 1. Ask a student to read the direction for the part of step 6 on which they are working. 2. Ask a student to paraphrase what they are to do for that part of step 6. 3. Share one example of the kinds of responses students should be thinking about and have them write that example on their Argument Tool. This will be particularly important for step 6c as students should write all types of evidence that could support the idea, not just evidence they have. 4. Ask a student to share another example. 5. Let students work on that part of step 6 with their small group. 6. When all groups are finished, ask a few students to share their ideas with the large group. 7. Repeat the process for each part of step 6. ● Use the responses in **RED** that can be found in the SE key to support your use of probe and challenge questions as students share their ideas. ● Optional Process: The seven-step process described above can be modified so that students can get out of their seats during step 6 and share their ideas with a person from another group. In doing so, students would be asked to find a person from another group and have a "standing meeting." During this meeting, the partners are to stand and share, in turn, how their group responded to the questions on that part of the Argument Tool. The partners should modify or add to their tool as needed based on what they learned. Please know that it may still be beneficial for assessment purposes for one or two students to share their responses in a whole-class discussion after each part.	

7. Scientists engage in argument to get feedback and refine their own ideas. One way this occurs is through presentations. A scientist will write a paper that makes a claim that is supported by evidence and reasoning. They will then share this paper with a group of interested scientists. Depending on their own ideas, individual scientists within the group may agree, disagree, or question the argument that is being presented.

   You will model aspects of this argumentation process in the next step. Check off each step as you complete it.

   a. Exchange your part of the Argument with other members of your team.
   b. Read your partner's part of the Argument.
   c. Ask questions to clarify your understanding of what your partners wrote.
   d. Provide feedback on sticky notes. Write at least two questions or pieces of feedback on your partner's part of the Argument. What you write should help your partners improve their argument. Place each sticky note on your partner's Argument Tool near the information that generated your question or feedback.
   e. Return the Argument Tool and sticky notes to your partner.
   f. Read through the sticky notes on your work. Decide if you agree with what is written. If you agree, revise your work in a different color. If you do not agree, write a statement on the back of the sticky note to explain why you are not taking the advice.

8. Submit to your teacher a completed argument tool with your team member's names on it.

Implementation	Notes
STEPS 7–8: Let students know that they are now to use the relevant evidence they listed in step 6 to create two separate claims. Remind students that the two claims need to be based on the evidence and that one claim may be stronger and of more quality than the other. They should refer to ideas posted around the room if they are having trouble but tell them that they are not required to use claims based on ideas from the list. Once they have written the two claims with evidence, let students know they need to write a short critique of the quality and strength of evidence that supports Claim A and Claim B. - Remind students that a strong claim is supported by evidence and uses logical thinking and reasoning to link information, inferences from data, and science ideas back to the claim. The critique they will create focuses on the strength of these links and whether the evidence is sufficient and adequate to support the claim. - Ask students to refer to the Communicating in Scientific Ways chart (STeLLA Strategy 4) as they complete steps 7 and 8. - As before, use probe questions to reveal student thinking (STeLLA Strategy 2) and challenge questions to move their thinking forward (STeLLA Strategy 3). These strategies will be especially useful as students are critiquing both claims. Focus your questioning on supporting evidence. The links students are making among information, inferences from data, and science concepts (evidence) and the claim are particularly important to the argumentation process. - Following are example questions: - Say more about why you think that is weak evidence. (Probe) - S2, can you paraphrase S1's reasoning? (Probe) - OK, so you believe that that piece of evidence strongly supports Claim A and you have adequate reasoning for it. But how does this piece of evidence also support Claim B? (Challenge) - The evidence you suggest does strongly support Claim B, but is the evidence sufficient? (Challenge)	

9. During this unit, you used one primary crosscutting concept, cause and effect, to help you explain what causes populations of organisms to change over time. You have explained what caused changes in the stickleback fish population in Loberg Lake and what caused changes in medium ground finches on Daphne Major. How did thinking about "cause and effect" help you explain the changes (or not)?

   Responses will vary.

   I learned that when a question asks for a "cause" then I need to look for an effect and then evidence for the cause.

   I learned that even though the CCC is "cause and effect" that I have to be clear about the effect before I can explain the cause.

   Thinking about cause and effect didn't really help me. I just answered the question. I used patterns/stability and change more than cause and effect.

   It didn't help me this time, but maybe it will in the future.

10. How confident are you that you can answer this unit central question completely**, "What causes populations of organisms to change over time?"** Circle a number to show your confidence.

   Not very confident 1 2 3 4 Very confident

Implementation	Notes

• **STEP 9:** Students are to write a scientific argument based on which claim they think is best. Their scientific argument must include
  ○ the scientific question,
  ○ a claim,
  ○ relevant evidence that supports the claim, and
  ○ scientific reasoning that critiques the evidence and evaluates the claim.
• Let students know that this is a similar process to what they used to complete their scientific explanation during the last lesson, and they should refer to that process if needed. However, the difference with this task of writing a scientific argument is that they will be explicitly adding the critique they completed in step 8 to complete the argument.
• **STEP 10:** Let students know that the rebuttal should focus on the critique that was completed in step 8. The rebuttal should focus on the strength of evidence and reasoning to support the claim.	

Lesson 5: Explaining Changes in Loberg Lake Stickleback

Phase of Lesson: *Finches in a Drought—Activity Follow-up*

Main Learning Goal: The factors of natural selection that explain the changes in one population are generalizableand can be used to explain changes in other populations.

Focus Question: What causes populations of organisms to change over time?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms thatare better able to survive and reproduce in that environment.

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Time: 15 Minutes

STeLLA Strategies

- Strategy 1: Ask questions to elicit student ideas and predictions
- Strategy 2: Ask questions to probe student ideas and predictions
- Strategy 3: Ask questions to challenge student thinking
- Strategy 5: Engage students in analyzing and interpreting data and observations
- Strategy 7: Engage students in constructing explanations and arguments
- Strategy 8: Engage students in using and applying new science ideas in a variety of ways and contexts

Science Ideas

- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A favorable trait variation *may* help an organism survive and reproduce.
- If over time a certain selection pressure continues,a favorable trait can become more prevalent in the population.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- Natural selection leads to perfection.
- Natural selection and evolution are equivalent terms.

11. How has your thinking changed, or not, about the causes for changes in a population over time? If your thinking changed, which activity was most influential and why?

Implementation	Notes
Activity Follow-up ● **STEP 11:** Meta Moment ● Decide whether to have students write a response or conduct a think-pair-share focused on the question. ○ How has your thinking changed, or not, about the causes for changes in population overtime? If your thinking changed, which activity was most influential and why?	

Lesson 5: Explaining Changes in Loberg Lake Stickleback

Phase of Lesson: *Summarize and Synthesize Ideas*

Main Learning Goal: The factors of natural selection that explain the changes in one population are generalizableand can be used to explain changes in other populations.

Focus Question: What causes populations of organisms to change over time?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms thatare better able to survive and reproduce in that environment.

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Time: 15 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy I: Summarize key science ideas

Science Ideas

- More individuals are born than can survive and reproduce.
- All individuals in a population have the same traits, but there are different versions of the trait in different individuals in the population.
- Among individuals in a population, there is competition for limited resources. This competition could be for food, habitat, or survival from being eaten.
- Some of the differences in a trait will help an individual survive longer and/or produce more offspring.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- Natural selection leads to perfection.
- Natural selection and evolution are equivalent terms.

Implementation	Notes
Summarize and Synthesize Ideas ● Ask students to think about how well Darwin's ideas of natural selection applied to the changes that occurred to the finch population on Daphne Major. They should think about the evidence and science concepts/ideas they used to support their claim. Also, refer them to the ideas that were written on the board during step 1. ● Have students do a quick turn-and-talk (1 minute—30 seconds per partner) to share their ideas with a partner. Once the minute is over, ask students to participate in a popcorn-share strategy about their ideas. Add any new ideas to the list of ideas that was started during step 1. Also, checkmark or star any student-shared ideas that relate to ideas that are already up on the board. ● Let students know that today they applied Darwin's idea about natural selection to a population of organisms other than stickleback fish with a great degree of success. Next class period, they once again focus on the unit central question, "What causes populations of organisms to change over time?" as they complete an end-of-module assessment. ● EXIT TICKET: Before students leave the classroom, ask them to think about how their ideas concerning cause and effect have changed as a result of completing the Natural Selection lessons. Once they are done thinking, they need to write a four- to five-sentence paragraph on a separate sheet of paper that describes how their thinking has changed. They will then hand in this paper before leaving the classroom.	