Stability & Change in Populations Over Time--Antibiotic Resistance

<table>
<tr><td colspan="2">This 5E model for instruction may be useful in connecting the concepts of why antibiotics are not effective against viruses (viruses compared to living organisms) and the theory of natural selection and speciation.</td></tr>
<tr><td colspan="2" align="center">Student Science Performance</td></tr>
<tr><td>Grade: 9-12 Biology</td><td rowspan="2" align="center">Title:
MRSA Stay or MRSA Go?</td></tr>
<tr><td>Topic: Antibiotic Resistance</td></tr>
<tr><td colspan="2">Performance Expectation for GSE:
SB6e: Develop a model to explain the role natural selection plays in causing biological resistance.
The initial focus is on antibiotic resistance but will relate to pesticide resistance in the elaborate section.
Secondary GSE:
SB6d. Develop and use mathematical models to support explanations of how undirected genetic changes in natural selection and genetic drift have led to changes in populations of organisms.
SB6a. Construct an explanation of how new understandings of Earth's history, the emergence of new species from pre-existing species, and our understanding of genetics have influenced our understanding of biology.</td></tr>
<tr><td colspan="2">Performance Expectations for Instruction:
Investigate how a population with variations may shift over time in response to external factors.
Group Performance: (Engage and Explore)
1. Obtain information from two scenarios of staph infection.
2. Ask questions to develop a model and construct an explanation for the cause of the different responses shown by the staph infections to the same treatment.
3. Carry out investigations (the antibiotic resistance exploration activity) to obtain data for evidence.
4. Analyze and interpret the data to refine your model and explanation constructed for the cause of the different responses shown by the staph infections to the same treatment.
Individual Performance: (Explore)
5. Write an argument for your explanation supported by evidence from the investigation.
Group Discussion: (Explore and Explain)
6. Use the evidence and explanations shared from others to refine or confirm your model and argument.
Teacher Reflection: (Explain)
7. Reflect on students' ability to develop an argument where the explanation is supported by evidence.
8. Reflect on students' ability to conclude that variations in S. aureus cause populations to shift over time & the effect of antibiotic resistance seen in staph infections is supported by evidence in the scenarios & activity.
Group Performance: (Elaborate)
9. Obtain information regarding pesticide resistance in plants, insects, or fungi.
10. Ask questions to develop a model and construct an explanation for the cause of the responses shown by different populations of pests.
Individual Performance: (Elaborate and Evaluate)
11. Write an argument for your explanation that relates to gathered information and evidence supporting the development of antibiotic resistance in bacteria.
Group Discussion: (Elaborate)
12. Use the evidence and explanations shared from others to refine or confirm your model and argument.
Teacher Reflection: (Evaluate)
13. Reflect on students' ability to develop an argument where the explanation is supported by evidence.
14. Reflect on students' ability to conclude that variations in bacteria, plants, insects, and fungi cause populations to shift over time & the effect of antibiotic and pesticide resistance seen in real-world scenarios is supported by evidence.

Additional notes on student supports</td></tr>
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Materials for Exploring Activity

Each partner group of 2 will need:

- 20 mini-marshmallows
- 8 skittles of any color
- 1 toothpick
- 1 paper plate
- 1 paper cup

For a class of 30 with 15 partner groups:

- 300 mini-marshmallows
- 120 skittles of any color
- 15 toothpicks
- 15 paper plates
- 15 paper cups

Students will continuously be obtaining, evaluating, and communicating information. This is not a linear process. Students should be communicating through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon** The overuse and improper use of penicillin for staph infections have led to the evolution of MRSA (methicillin-resistant *Staphylococcus aureus*). The following are possible OER resources: • CK12: Evolution of Resistance in Bacteria - Advanced (This article focuses strictly on the evolution of superbugs). • CK12: Emerging and Reemerging Diseases - Advanced (This article incorporates additional diseases like Lyme Disease). • WikiMedia Commons: Images related to "Antibiotic Resistance" (This is a resource bank of OER images that are useful in helping students understand how to model of the evolution of antibiotic resistance using information from the scenarios.) Additional notes on Topic, Focus, and Phenomena.
	Obtaining Students obtain information from the scenarios of two fictitious patients: Patient #1 has a staph infection and is treated successfully with one round of penicillin. Patient #2 has a staph infection but is treated unsuccessfully with multiple rounds of penicillin. His doctor results in treating him with a combination of strong antibiotics and a surgical procedure to remove the infection from his wounds. *Teacher Notes: The following scenarios are a guide. Use any scenarios that would appeal to your students to convey the concept of antibiotic resistant bacteria. Give students scenarios as short print articles or in a teacher-led description of two images.*
	Evaluating Students construct an explanation for the difference between the two infections using information from the scenarios. *Teacher Notes: Be sure to clarify that staph infection is caused by the bacterium Staphylococcus aureus. Penicillin is an antibiotic. Antibiotics target and kill bacteria.*
	Communicating Students develop a model to demonstrate how the bacterium that caused the infections responded differently to the antibiotic treatments. *Teacher Notes: Students should be able to provide a simple conclusion that demonstrates there is a difference between the bacteria that infected patient #1 and were killed with penicillin and the bacteria that infected patient #2 that were not killed by penicillin.*

Exploring Revising Model	*Obtaining* Students carry out the following hands-on investigation to obtain information: Activity Handout Activity Handout with supports for struggling students Activity Slides: **Antibiotic Resistance Mini-Lab (Segment 1)—located in the Teacher Resource Link** Students develop a line graph (mathematical model) to track the populations of the normal bacteria (marshmallows) and the resistant bacteria (hard candy). *Teacher Notes: When giving directions for removing the bacteria from the plate, tell students that each antibiotic only has one method of action and for this antibiotic that is to penetrate the cell wall. This should get students to think about "stabbing" the marshmallows rather than trying to "sweep" the "bacteria" off the plate. Most students will not be able to remove any hard candy by "stabbing" them with the toothpick because they cannot penetrate the tough outer coating. This will lead to an increase in the number of "resistant bacteria" on the plate.*
	Evaluating Students analyze and interpret data of the bacterial populations collected during the activity. *Teacher Notes: Have students compare results with other groups in the class. Discuss any differences. Some students may have been able to remove the hard candy from the plate. If applicable, use this to emphasize different treatments for bacterial infection but also explain that each antibiotic has a specific method of action and therefore it would not work in every case.*
	Communicating Students revise the model developed in the ENGAGE to demonstrate how the bacterium that caused the infections responded differently to the antibiotic treatments.
Explaining Finalizing Model	*Obtaining* Students obtain information about the following concepts: random variations, fitness, natural selection, survival of the fittest, and successive generations. *Teacher Notes: You may preview binary fission to explain how a bacterium reproduces. That allows the passage of the random variation in DNA to be passed on the successive generations. The actual process of binary fission can be taught in more detail with asexual reproduction in Molecular Genetics.*
	Evaluating Students construct explanations that compare the ENGAGE scenarios and the EXPLORE activity and relate them to the following concepts: random variations, fitness, natural selection, survival of the fittest, and successive generations. Students construct explanations of the causes of antibiotic resistance and suggest alternatives.

	Teacher Notes: Common causes of any resistance is the overuse and/or misuse of antibiotics or pesticides. Students may develop alternatives to combat man-made resistance in non-resistance forms. Students may extend to developing alternatives to combat organisms that have already developed resistance.
	Communicating Students finalize the model developed in the ENGAGE and EXPLORE to demonstrate how the bacterium that caused the infections responded differently to the antibiotic treatments. ***Formative Assessment of Student Learning*** *The following may be assessed through discussions, writings, or analysis of images/models.* Students use evidence from the ENGAGE scenarios and the EXPLORE activity to argue the claim that bacterial populations that have random variations will shift to the random variation that increases fitness. Those that are more fit for the environment will survive and reproduce. That allows for the random variation that increased fitness may be passed on to successive generations.
Elaborating Applying Model to Solve a Problems	**Phenomenon** Farmers have a difficult time controlling the amount of unwanted pigweed growing in their crops because the pigweed does not respond as well to glyphosate (Round-Up) as it did in past years. *Teacher Notes: The focus of this elaboration model to is expand the student's knowledge of developing antibiotic resistance through the process of natural selection to the development of pesticide resistance. Use any phenomenon that would engage specific learners. Students may benefit from differentiated topics that relate to herbicide resistance in plants, insecticide resistance in insects, or fungicide resistance in fungi.* The following is a possible OER resource: Youtube via CreativeCommons.org: Evolution of Resistance (This video focuses on insecticide resistance and compares it back to developing antibiotic resistance through natural selection).
	Obtaining Students ask questions and obtain information about the history of pigweed and the widespread use of glyphosate as a pesticide.
	Evaluating Students analyze and interpret data that support the idea that pigweed have developed resistance to glyphosate. Students construct explanations of the causes of pigweed resistance and suggest alternatives. *Teacher Notes: Common causes of any resistance is the overuse and/or misuse of antibiotics or pesticides. Students may develop alternatives to combat man-made resistance in non-resistance forms. Students may extend to developing alternatives to combat organisms that have already developed resistance.*

	Communicating Students develop a model to demonstrate how the pigweed population has changed over time in response to using glyphosate as a pesticide. Students use evidence from the EXPLAIN to engage in argument to determine that pigweed have developed resistance like how bacteria develop resistance to antibiotics.
Evaluation	***Assessment of Student Learning***
	In models: Students develop models to demonstrate the process of antibiotic and pesticide resistance. *In writing:* Students use evidence from models to argue the claim that populations that have random variations will shift to the random variation that increases fitness. Those that are more fit for the environment will survive and reproduce. That allows for the random variation that increased fitness to be passed on to successive generations. This can occur in bacteria in the form of antibiotic resistance or in plants, insects, or fungi. *In writing:* Students construct explanations of the causes of resistance in bacteria, plants, insects, or fungi and suggest alternatives to prevent an increase in the number of species developing resistance.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Obtaining, evaluating, & communicating information • Constructing explanations • Engaging in argument from evidence • Analyzing & interpreting data • Developing & using models
Crosscutting Concepts	• Cause & effect • Stability & change
Disciplinary Core Ideas	LS4.B Natural Selection • Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information--that is, trait variation--that leads to differences in performance among individuals • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.C Adaptation • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline--and sometimes the extinction--of some species.

Antibiotic Resistance Lab

Introduction:

Frequently, people will go to the doctor when they get sick and the doctor will prescribe a type of medication called antibiotics to help them feel better. This only works if the sickness is caused by bacteria and the antibiotics are taken correctly. If these conditions are not met, then the antibiotic may be contributing to resistance. Define resistance to the best of your ability (hint: Buildings not being knocked down by wind is showing that the building has resistance to the wind).

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Now that you have a basic idea of what resistance is think about what that means for bacteria and antibiotics. What is going to happen to the bacteria exposed to antibiotics, are they all going to die? Will some survive? What will happen to the population of bacteria over time? Write a hypothesis below.

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Task:

1. Obtain the following materials:
   20 mini-marshmallows   8 candy with hard covering of any color   1 toothpick
   1 paper plate   1 paper cup
2. Put 8 mini-marshmallows and 2 candy with hard covering on the same plate.
3. Using the toothpick, pick up the mini-marshmallows or candy with hard covering one at a time and place them in the cup. Pick up as many as possible in 7 seconds.
4. Count how many are remaining and record this data in the table below.
5. The remaining mini-marshmallows and candy with hard covering will now undergo reproduction by fission. Double the number of mini-marshmallows and candy with hard covering on the plate.
6. Repeat steps 3-5 twice for a total of 3 rounds and record all data in the table below.

Data Collection:

Time	# of normal bacteria (mini marshmallows)	# of mutated bacteria (candy with hard covering)
Beginning (Step 0)	8	2
After 1st Dose of Hand Sanitizer (D1)		
Remaining Bacteria Reproduce (R1)		
After 2nd Dose of Hand Sanitizer (D2)		
Remaining Bacteria Reproduce (R2)		
After 3rd Dose of Hand Sanitizer (D3)		
Remaining Bacteria Reproduce (R3)		

Graph:

Construct a line graph showing the change in the number of bacteria over time.

Conclusions:

What does the paper plate represent?

What do the white mini marshmallows represent?

What do the candy with hard covering represent?

What does the process of removing them represent?

What does the process of doubling the amount left represent?

Does this change your view on using hand sanitizer?

What was the mutation and where did it come from?

Where do you see the following between the marshmallows and candy with hard covering?

Competition?

Survival of the Fittest?

Variation?

Reproductive Success?

Return to Instructional Segment

Antibiotic Resistance Lab

Introduction:

Frequently, people will go to the doctor when they get sick and the doctor will prescribe a type of medication called antibiotics to help them feel better. This only works if the sickness is caused by bacteria and the antibiotics are taken correctly. If these conditions are not met, then the antibiotic may be contributing to resistance.

Resistance is when something is not harmed, or the harm is lessened by another outside force. Examples are like buildings are resistance to the force of wind or your skin is resistant to being cut.

Now that you have a basic idea of what resistance is think about what that means for bacteria and antibiotics. What is going to happen to the bacteria exposed to antibiotics, are they all going to die? Will some survive? What will happen to the population of bacteria over time? Write a hypothesis below.

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Task:

1. Obtain the following materials:
   20 mini-marshmallows　　8 candy with hard covering of any color　　1 toothpick
   1 paper plate　　1 paper cup
2. Put 8 mini-marshmallows and 2 candy with hard covering on the plate. This is your beginning population.
3. Using the toothpick, pick up the mini-marshmallows or candy with hard covering one at a time and place them in the cup. Pick up as many as possible in 7 seconds.
4. Count how many are remaining and record this data in the table below for the remaining population.
5. The remaining mini-marshmallows and candy with hard covering will now undergo reproduction by fission. Double the number of mini-marshmallows and candy with hard covering on the plate. Record this in the box for population after reproduction.
6. Repeat steps 3-5 twice for a total of 3 rounds and record all data in the table below.

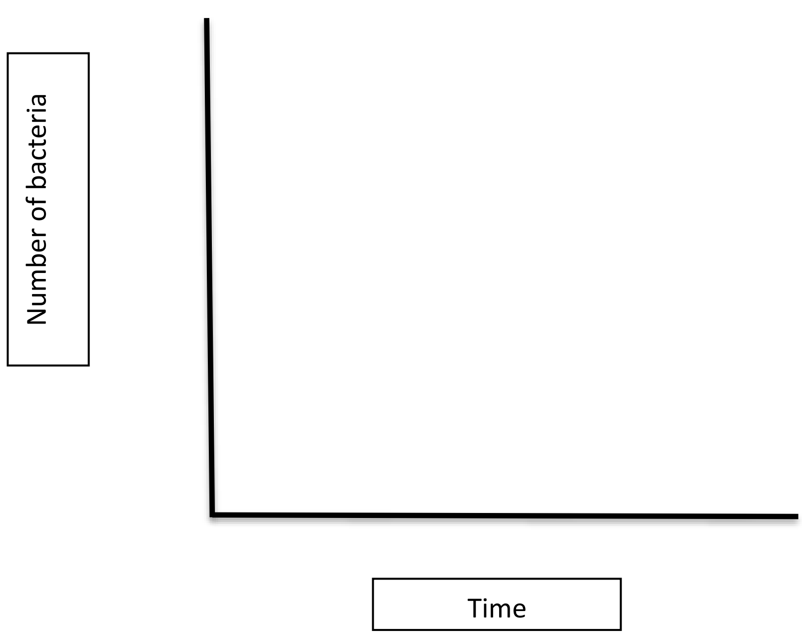
Data Collection:

Time	# of normal bacteria (mini marshmallows)	# of mutated bacteria (candy with hard covering)
Beginning population	8	2
Remaining Population		
Population after reproduction		
Remaining population		
Population after reproduction		
Remaining population		
Population after reproduction (final population)		

Graph:

Construct a double line graph showing the change in the number of bacteria over time. Use the graph template below to help. In the legend provide information about how you drew the lines or what color you used for the lines so that anyone can read your data.

Title: ______________________________



Graph legend:

Marshmallows

Hard candy

Conclusions:

What does the paper plate represent?

What do the mini marshmallows represent?

What do the candy with hard covering represent?

What does the process of removing them represent?

What does the process of doubling the amount left represent?

Does this change your view on using antibiotics?

What changed in the bacteria to give it a hard covering? Justify.

Where do you see the following between the marshmallows and candy with hard covering?

Competition?

Survival of the Fittest?

Variation?

Reproductive Success?

Return to Instructional Segment

Stability and Change in Populations Over Time
GSE: **SB1a, SB4a, SB4c, SB6a, SB6b, SB6c, SB6d, SB6e**

Anchoring Phenomenon:
Antibiotics do not work on viruses and may become less effective on bacteria over time.

Topic	Focus	Lesson Phenomenon	GSE/Notes/Language
Virus Evolution	Brief overview of how viruses can change over time in response to selection pressures.	The flu vaccine is updated annually in response to the changing flu virus.	SB6e Viral structure--protein capsid and nucleic acid Overview of fitness and adaptations
Viruses vs Bacteria (and other living organisms)	Viruses are nonliving particles. Brief overview to compare the two structures to help review terms {cell wall, prokaryote} from 7th Grade Life Science. Compare human cells with bacteria to help review terms {nucleus, eukaryote}.	Viruses do not respond to antibiotics.	SB4c/SB1a/SB4a--Key characteristics to define differences: cell wall, nucleus, cell membrane Emphasis: Viral structure includes: --protein capsid and nucleic acid Bacterium structure includes: --cell wall, cell membrane, prokaryote, no nucleus, DNA Human cell structure includes: --cell membrane, eukaryote, nucleus, DNA Viruses are not made of cells. Viruses cannot reproduce without a host cell. Antibiotics target prokaryotic cells.

Antibiotic Resistance	Random genetic variations allowed for natural selection to select for existing resistant bacteria. Fitness/survival of the fittest Relate to pesticide resistance to demonstrate this concept is also seen all other organisms.	Some staph infections (MRSA) do not respond to antibiotics.	SB6e MRSA Stay or MRSA Go? Antibiotic Resistant Exploration Activity with Skittles and Marshmallows Random genetic variations may be beneficial, harmful, or have no influence on fitness. This will be emphasized in Structure and Function of Molecular Genetics Fitness is the ability to be best adapted for survival in an environment.
Genetic Drift	Contrast antibiotic resistance, where non-resistant (less fit) alleles are removed from population, to a population bottleneck where alleles are randomly removed regardless of fitness.	The North American bison today are different from their wild ancestors.	SB6d/SB5a/SB5e Differentiate between resistance coming from natural selection where there was an advantage to the survival of some organisms, and genetic drift where survival is due to random chance alone. These concepts will be emphasized in the molecular genetics and heredity units. Gene pools are the traits available for reproduction in an area. Gene flow is the immigration or emigration of these traits into or out of an area.
	Introduce the founder effect with genetic drift to make the connection between bottleneck events and natural selection with Darwin's finches.	The Amish have a high rate of polydactyly. The Fugates of Kentucky have blue-tinted skin.	

			Bottleneck and founder effects can be seen in living organisms.
Speciation	Darwin's finches demonstrate the founder effect through adaptive radiation where natural selection caused speciation.	Birds have different types of beaks that are specific to the resources in their habitat.	SB6a/SB5e Use stabilizing, directional, and disruptive selections to model trait shifts in populations. Include Darwin's theory, his influences (Lamarck and Malthus), and his theory of natural selection. Speciation occurs from reproductive isolation (geographic, temporal, or behavioral). Physical or behavioral adaptations and plant tropisms can increase fitness. Compare natural and artificial selection.
	To speed up the process of natural selection, humans are now influencing speciation through the process of artificial selection.	Humans encouraged dogs to evolve from wolves.	
Patterns of Biodiversity	Major events in time cause major shifts in biodiversity; history of life; history of the Earth	When the dinosaurs became extinct, small mammals were then able to grow rapidly in size.	SB6b/SB5a/SB5e Use an overview of the 5 mass extinctions in conjunction with the evidence of speciation (fossil record/comparative anatomy) to emphasize natural selection is the driving force of speciation and can cause great shifts in biodiversity.
Evidence of Speciation	Fossil record	The modern horse is physically different from	SB6c

	Use in conjunction with the 5 mass extinctions.	its ancestor.	Darwin concluded the first two evidences but did not have knowledge of DNA/biochemical evidence of evolution. DNA is emphasized in another unit, so a brief overview is enough here. Modeling theories of evolution (gradualism and punctuated equilibrium) in cladograms and/or phylogenetic trees may be useful in connecting this instructional segment with Patterns in Living Systems.
	Comparative anatomy; homologous structures through adaptative radiation; analogous structures through convergent evolution	Humans, dolphins, and bats are more closely related; however, dolphins resemble sharks and bats resemble birds more than they resemble humans.	
	Embryology The embryos of vertebrates look very similar in the early stages of development. Vestigial structures	The embryos of snakes have leg buds; the embryos of whales have teeth; the embryos of humans have tails.	
	Biochemical evidence; more closely related organisms have more similar DNA. Use phenomenon to relate back to genetic drift of human populations.	Companies will sequence your DNA to determine genetic relatives.	

Anchoring Phenomenon:

Antibiotics do not work on viruses and may become less effective on bacteria over time.

Students will explain the phenomenon using the following concepts:

- Antibiotics target bacteria which are prokaryotic cells.
- Antibiotics do not work on viruses because they do not contain the same structures as living cells.
- Antibiotics may become less effective on bacteria over time because of random variations that may increase their fitness and cause genetic drift in a population.
- Viruses are like bacteria because they demonstrate random variations that may increase their fitness and cause genetic drift in a population.
- Bacteria and viruses can evolve into different strains that are identified through the DNA evidence.

Return to Instructional Segment

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. The teacher should model how to create and read a graph including labeling all the parts of the graph. 2. The teacher should provide graph paper so that students do not have to free hand a graph. Many students will get caught up in the drawing and forget basic graphing concepts. 3. The teacher should provide some graph reading practice for students that have trouble constructing the graph.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. Individual performance (explore, elaborate and evaluate): The teacher should allow the students to show their knowledge in various ways. Some examples of ways that students could show their knowledge are writing an explanation, drawing an image and adding captions, giving a verbal explanation, creating a slideshow, or creating a cartoon. Make sure to emphasize to students that the explanations should include supporting evidence from the investigation.
2. Teacher reflections for struggling students:
   -The teacher should reflect on grouping of students. Was it beneficial and were all students able to contribute? Why or Why not?
   -The teacher should reflect on supports for struggling learners. Were the supports enough for the student population? Why or why not? Then make a list of other supports that the teacher can try in the classroom.

Phenomenon:

1. For the article provided the teacher can lead a read aloud or facilitate a paired reading to help struggling readers with the material.
2. Provide a graphic organizer to help students identify the topics covered in the articles and assist in the students identifying questions that they have from the reading.
3. Short videos are a good way to engage students, as well. The teacher can find two videos that have the same concept as the articles. The teacher is looking for 1 video with a patient that does respond to antibiotics and 1 video with a patient that does not respond to antibiotics.

4. When evaluating the video or article, students can use various formats to explain the difference between the 2 scenarios such as drawing a picture, writing an explanation, giving a verbal explanation or making a slide to show their understanding.
5. Be sure to help the students understand that viruses and bacteria are different things and that antibiotics can only treat bacteria.

Exploring:

1. The teacher can lead a read aloud or partner read the beginning of the lab to help with struggling readers and students that have processing issues. Have the students highlight the important information to refer to as they work. Two versions of the lab are available above and the second version includes supports for struggling students that need the additional support to be successful.
2. The teacher could provide an example of graphing the data on the board by either using one groups data or making up a data set to set expectations and lessen anxiety over constructing the graph correctly. Then teacher can then walk around to check graphs as the students work and quickly correct misconceptions.
3. The teacher could provide a line graph that is like the one that the students have created for them to check their work prior to comparing with other students. This will cut down on embarrassment if the students have errors in their graphs.
4. Students may need some assistance in revising their model at first. If students are struggling then attempt to support them using a card sort, demo or other scenario to help them make connections to revise their model.

Explaining:

1. This is vocabulary that students may or may not have been exposed to in the past. Even if struggling learners have seen it in the past there may be trouble with recall. Provide students with images, videos and descriptions to help them understand the concepts and build on their knowledge or recall the vocabulary terms as needed.
2. Assessment options should be presented for struggling learners. Options could include discussions, writing, analysis of images or models.

Elaborating:

1. Show students an image of both pigweed and round up. Many students will have seen these things in real life and not realize what they are called. Given an image they may be able to connect it to their prior knowledge with more information.
2. Remind students that they can refer to the lab to help explain the concept of insecticide resistance.

Evaluating:

1. Students may need additional time to construct a model
2. Writing can be a major struggle for some students. Some choice as to how students express their knowledge may be warranted. Students could express their knowledge in the form of a picture, cartoon, slides presentation, or even verbally.

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