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 about 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.</td></tr>
</table>

Materials for Exploring Activity

Each partner group of 2 will need:

- 20 mini-marshmallows
- 8 pieces of small candy of any color
- 1 toothpick
- 1 paper plate
- 1 paper cup

For a class of 30 with 15 partner groups:

- 300 mini-marshmallows
- 120 pieces of small candy 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 the evolution of antibiotic resistance using information from the scenarios.)

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 treated him with a combination of strong antibiotics and a surgical procedure to remove the infection from his wounds.

Teacher Hint: The above 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 Hint: 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 Hint: 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: Antibiotic Resistance Lab Activity Slides: Antibiotic Resistance Presentation Students develop a line graph (mathematical model) to track the populations of the normal bacteria (marshmallows) and the resistant bacteria (candy pieces). *Teacher Hint: Limit the directions for removing the bacteria from the plate other than you can only use the toothpick. Most students will not be able to remove any pieces of candy by "stabbing" them with the toothpick, because they cannot penetrate the tough outer coating. However, some students may "sweep" the candies off the plate with the side of the toothpick into the cup. If applicable, use this to emphasize different treatments for bacterial infections.*
	Evaluating Students analyze and interpret data of the bacterial populations collected during the activity. *Teacher Hint: Have students compare results with other groups in the class. Discuss any differences. Some students may have been able to remove the candy pieces from the plate. If applicable, use this to emphasize different treatments for bacterial infections.*
	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 Hint: 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 Hint: A common cause 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 to 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 Hint: The focus of this elaboration model is to 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 has developed resistance to glyphosate. Students construct explanations of the causes of pigweed resistance and suggest alternatives. *Teacher Hint: 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 EXPLAIN to engage in argument to determine that pigweed has developed resistance similar to 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 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** National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.*
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.