The Antibiotic Resistance of MRSA: Teaching Natural Selection with Literacy Development for English Learners

Introduction

Both Next Generation Science Standards (NGSS; Achieve 2013) and Common Core State Standards (CCSS) for English Language Arts (Common Core State Standards Initiative, 2010) promote *discipline-specific* forms of reasoning and communicating, such as (1) writing explanatory texts, (2) arguing from evidence about disciplinary ideas, and (3) analyzing the purpose and target audience of a text, all while demonstrating content knowledge. There is a deep connection between NGSS's focus on using core science ideas while engaging in such discourses and CCSS's attention to craft/structure and audience/purpose of the very same discourses. Thus, to promote both science learning *and* literacy development in a science activity, it is imperative to consider an *integrated* approach to language, literacy, and science, rather than treat language and content learning as separate domains.

Considerable research indicates that integrating contextualized inquiry-based instruction with opportunities for literacy development improves science learning for all students, particularly for those who speak a native or home language other than English, i.e., English learners (ELs) (Cervetti, Pearson, Barber, Hiebert & Bravo 2007; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada 2008; Tolbert, Stoddart, Lyon, & Solis 2014). The improvement of science learning opportunities for ELs is critical given that they represent a significant proportion of the U.S. school-age population (nearly 22% speak a language other than English at home), yet have limited to no opportunities to access the core secondary curriculum (Bunch 2013; National Center for Educational Statistics 2011). The restrictions and reduction in many states on specialized sheltered and bilingual instruction programs designed to increase ELs' access to content widens this achievement divide (Markos 2012). Thus, it is critical that science taught in mainstream high school classrooms, which may contain ELs or former (designated) ELs, respond to the opportunity gap between them and English only students. In particular, ELs need access to rigorous and meaningful science, as well opportunities to develop literacy in the context of learning science.

The Antibiotic Resistance of MRSA exemplifies how science teachers in multilingual high school biology classrooms (grades 9-12) can facilitate students' sense-making of evolution by natural selection, through contextualized, real-world issues while *simultaneously* helping students develop disciplinary literacy.

Theoretical Background: Using the SSTELLA Framework to inform Science Teaching for ELs

The activity described in this article was developed through the National Science Foundation funded Secondary Science Teaching with English Language and Literacy Acquisition (or SSTELLA) Project. SSTELLA aims to develop tools, such as exemplar science units, for novice science teachers to learn how to promote and assist ELs in the productive and authentic use of language when learning science. SSTELLA also studies how novices become prepared to teach science in multilingual classrooms, including changes in knowledge, beliefs, and practice over time. SSTELLA has used tools developed, including *The Antibiotic Resistance of MRSA*, to train experienced science teachers about language and literacy integration, and has piloted various tasks from the unit with secondary science teachers. At its core, SSTELLA focuses on four interrelated instructional practices (described below) that align with both NGSS and CCSS for English Language Arts (Tolbert et al. 2014). Research indicates that these practices are supportive for all students, but are particularly effective for ELs.

Contextualize science activity: Science activities become contextualized when they are meaningful and relevant to students – i.e., connected to students' everyday experiences, home and community knowledge, local environment, and/or real world issues. The teacher not only provides

relevant examples, but also elicits students' own experiences that can be leveraged for deeper understanding of the content (Author forthcoming). Thus, contextualization is viewed as the gateway through which ELs can come to understand relationships between school science learning and their lived experiences outside of schools.

Promote scientific sense-making through scientific/engineering practices. Scientific sense-making refers to how students negotiate everyday and scientific ways of knowing, while developing increased awareness of the nature of science, via engagement in the scientific/ engineering practices described in *A Framework for K-12 Science Education: Practices, Cross Cutting Concepts, and Core Ideas* (National Research Council 2012). In particular, the focus on scientific modeling allows ELs to use language in a variety of ways as they generate representations of big ideas in science, such as "How species change over time," communicate and discuss those representations, seek evidence to test their models, and then refine them. As Windschitl (2009) notes, an ultimate goal of scientists is to defend explanations of natural phenomena, which happens through the refinement of models that fit the data available.

Promote scientific discourse: Science content and language intersect as students engage in specialized scientific oral and writt*en* language to reason through and communicate ideas, referred to as the discourse of science. ELs in particular need supportive opportunities to engage in productive academic talk, as well as time to write, evaluate, and discuss common discourses such as explanations and arguments. However, middle school and high students rarely have opportunities to explain or argue about natural phenomenon (Osborne & Patterson, 2011), which according to Windschitl (2008) is a central goal of scientists. Science education scholars argue that for students to develop a coherent understanding of science they must learn *how* science knowledge is constructed, presented, and shared.

Argumentation and explanation assist students in unpacking knowledge construction in science. In turn, argumentation and explanation promotes conceptual understanding, investigative competence, and understanding the epistemology and social nature of science (Driver, Newton, & Osborne, 2000; Osborne, Erduran, and Simon, 2004). These competencies extend outside of the school setting and a career in science; they allow individuals to be critical consumers of knowledge and participate in a democratic society. Teachers can press for evidence-based explanation and argumentation in a variety of activities (including science talks, lab investigations, or interpreting authentic science texts) and assist student understanding about (1) *how* to argue and explain, (2) *the role* of arguments and explanations in science, and (3) how to bridge their own everyday notion and ways of explaining and arguing with those forms accepted in the scientific community.

Promote English Language and Disciplinary-Literacy Development. According to Lee, Quinn, and Valdés (2013), the language of the science classroom "is grounded in colloquial or everyday language but moves toward the disciplinary language of science" (p. 228). Moje (2007) and others us the term disciplinary literacy to focus on cognition and learning, the discipline specific cultural and norms, and the cultural practices of the learners. Developing disciplinary literacy involves teaching ways of thinking and using language within disciplinary communities (Author forthcoming). For instance, the language of science texts requires making sense of dense clauses, hierarchically structured information, and a mixture of general academic vocabulary and highly specialized terms. Students can benefit from understanding both how the structure and content of science texts serves (1) particular purposes (list procedural steps for an investigation or provide a causal explanation given available evidence) and (2) particular audiences (expert in the field vs. members of the local community). Overall, this perspective proposes that supporting language and literacy in a science classroom is much more than addressing vocabulary recall or grammatical forms.

When transitioning to secondary classrooms, students face both (1) an increase in complexity of language genres associated with disciplinary reading, writing, speaking, and listening (Scarcella 2003) and (2) a decrease in authentic content learning opportunities (Bruna & Gomez 2008). To engage ELs in

content learning and language & literacy development, the teacher can do close readings of science texts to deconstruct the structure, including use of evidence, and promote interaction among students through reciprocal teaching (Palinscar & Brown 1984) or other cooperating learning strategies (e.g., jigsaw, numbered heads).

To summarize, the SSTELLA Framework views the relationship between science learning and English language and literacy development as reciprocal and synergistic. Through the *contextualized* and *authentic* use of language in scientific practices, students develop and practice complex language forms and functions. Simultaneously, with language functions such as explanations and arguments in science investigations, students make sense of abstract core science ideas and enhance their conceptual understanding as well as understanding of the nature of science. The challenge remains for secondary science teachers to infuse these practices into their classroom teaching.

Activity Background: Antibiotic Resistance of MRSA

Alexandar Ogston, a Scottish surgeon, first identified the Gram-positive bacteria, *Staphylococcus aureus*, in the late 1800s. Staph infections can cause mild illnesses (e.g., skin infections) to severe one (e.g., pneumonia and sepsis). The discovery of naturally occurring antibiotics, such as penicillin, by Alexander Fleming in 1928, allowed doctors to treat illnesses such as Staph infections. Penicillin was introduced in the U.S. and the U.K. by 1941; however, a short time afterward, a variant of *S. aureus* was identified that was resistant to penicillin. As new medical advances came, a slew of additional antibiotics were introduced that could counter these resistant bacteria: vancomycin in 1958 and methicillin in 1959. In 2007, the government released a startling new estimate that nearly 19,000 people in the United States had died in a single year after being infected with the methicillin-resistant form *Staphylococcus aureus* (or MRSA).

The purpose of this activity is to use the antibiotic resistance of MRSA as a real life example to help students construct an explanatory model, using the theory of natural selection, to account for the emergence of MRSA. In the process of making sense of the natural selection and the particular phenomenon of MRSA, students are supporting in reading scientific texts, which they can use as a guide to write their own explanation.

Grade Level

High School (grades 9-12)

Materials

Model Explanation – "New answer to MRSA, other 'superbug' infections: clay minerals?" (Appendix A)

Model Explanation – "Staphylococcus aureus Infections" (Appendix B)
Explanation Rubric (Appendix C)
MRSA videoclip: https://www.youtube.com/watch?v=bevhCDOoYeE#t=30
Document camera or smart board (to display and mark up texts)

Standards

Next Generation Science Standards (NGSS)

HS-LS4-2. Biological Evolution: Unity and Diversity
Students who demonstrate understanding can:

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction[1], (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

Common Core State Standards (Literacy in Social Sciences, Sciences, and Technical Subjects)

Writing 2 (grade 9-10): *Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processe*

Language functions associated with constructing explanations (Framework for English *Language Proficiency Development Standards corresponding to the Common Core State Standards and the Next Generation Science Standards (Council of Chief State School Officers, 2012)*

Receptive language functions: *Comprehend questions and critiques, explanations offered by others, and explanations offered by texts; coordinate texts and representations*

Productive language functions: *Communicate (orally and in writing) ideas, concepts, and information related to a phenomenon or system; provide information needed by listeners or readers; respond to questions by amplifying explanation; respond to critiques by countering with further explanation or by accepting as needing further thought; critique or support explanations offered by others*

WIDA English Language Proficiency Standards

Standard 4 (grade 9-12)*: English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science (i.e., the language of science)*

Procedure

The activity is intended to be enacted at the onset and at the end of a unit on natural selection. The procedure below (1) details what teachers would do on the first day (or two) of the unit to frame the unit and engage students in development an initial explanatory model, (2) suggests possible activities during the next five or so days that can provide evidence to test the model, and then (3) details how the unit would conclude by allowing students to revise their model and write the final explanation.
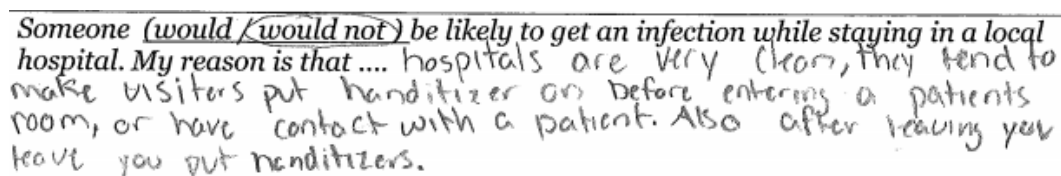
Part I: Unit Framing (Day 1)

1. Display an anticipatory question and instruct students to respond "yes" or "no" and give a reason (See sample student response in Figure 1)

Recall an experience with hospitals, such as when you…

(1) were injured,

(2) waited for your brother, sister, or cousin being born, or

(3) visited a sick family member or friend.

Also think about your own knowledge of hospitals.

Do you think someone could be harmed from bacteria while staying in a local hospital?

Someone (would / would not) be likely to get an infection while staying in a local hospital. My reason is that …. hospitals are very clean, they tend to make visitors put handitizer on before entering a patients room, or have contact with a patient. Also after leaving you leave you put handitizers.

Figure 1. Student Response to Anticipatory Question

2. Engage students in sharing with a partner first, then as a whole class. Probe student ideas to understand more about how to connect science learning to their own knowledge and experiences. Students might have heard about problems with "overusing" antibacterial products such as hand sanitizers, and the class can discuss some of the pros and cons of such products. Let students know that this is an important real-world problem and that a goal of the unit is to seek evidence to address the anticipatory question.

3. Show the first seventy-four seconds of the following YouTube clip: https://www.youtube.com/watch?v=bevhCDOoYeE#t=30 that depicts a newscaster in 2005 reporting on the increased presence of a "superbug" called Methicillin resistant *Staphylococcus aureus* (*or* MRSA). The clip ends with a reporter asking an expert: "What causes these so called Superbugs?" Stress to the

class that they will engage in many activities over the next week to explore "What causes Superbugs," which will help them understand the big idea: "How do species change over time?" The big idea question should be written and left on the board for the entire unit. Furthermore, teachers can emphasize the importance in mass and social media (such as news clips) of having legitimate sources (like an expert in the field) and that knowledge of science can help them come to make informed decisions about whether to trust sources and knowledge from such media.

4. Use a graphic organizer (e.g., Figure 2) to review important terms from the clip: "the species of interest," MRSA's relationship to this species," and "antibiotics." The word "resistance" can be introduced through a political cartoon (Figure 3) that plays on the multiple meanings of the word resistance: "to protect from antibiotics" and "to stand up to a political organization or power."

Figure 2. Vocabulary Graphic Organizer

Figure 3. Resistance Political Cartoon

Part II: Developing an Initial Explanatory Model (Day 1)

5. Conclude the day by displaying an abbreviated timeline (Table 1), indicating four key points related to MRSA. This timeline will be revisited on a later date.

Table 1. Initial Antibiotic Resistance Timeline

Late 1880s	1941	1961	Present

Staphylococcus aureus first identified by scientists	First resistance form of *Staphylococcus aureus* identified (resistant to penicillin)	First case of MRSA reported (resistant to penicillin and methicillin)	Over 60% of *Staphylococcus aureus* is resistant to methicillin)

Instruct students to individually create an outline (they can choose to organize/represent the outline however they want) to provide a tentative explanation about HOW the species *Staphylococcus aureus* changed (from 1880s to Present) so that over 60% is methicillin resistant. The outline should have both visuals and descriptions (or captions) to indicate this change. Remind students that throughout the week they will engage in activities that can provide evidence to improve their outline. "This is just an initial model that we will revise toward the end of the unit." Teachers can model how to outline by drawing a picture of a colony of bacteria on a petri dish to represent *Staphylococcus aureus* and then draw a petri dish next to the first one with some of the bacteria colored differently (representing resistance individuals).

Part III: Seeking Evidence to Test the Model (Days 2-7, depending of activities actually used)

6. Over the next week, engage students in a series of activities – see Table 2 (Passmore, Coleman, Horton, and Parker 2013) that investigate and provide evidence for four factors that, according to Darwin's theory of natural selection, influence how species change over time. In Table 2, ideas for "framing" and "exploring" the influential factors are given as well as a literacy task. Teachers can use alternative activities also known to facilitating student understanding of natural selection. The key idea is for teachers to allow students to make sense of the same evidence used by Charles Darwin to infer the mechanism of natural selection, in particular: population growth, hereditable genetic variation, competition, and differential reproductive success. Instead of piecing all four factors together for students, the teacher stresses that each activity provides new evidence that they will use to refine their initial model of how *Staphylococcus aureus* changed over time. Furthermore, in each activity teachers scaffold students' literacy development through tasks that allow them to read, write, and discuss authentic texts in the service of understanding natural selection.

Table 2. Influential Factors and Associated Class Activities[a]

Influential factor	Class activity
population growth	***Fish simulation:*** 1. Framing: Discuss a local population (e.g., school, community) – what defines that population and how it might have changed over time and why. 2. Exploration: Use online simulation at http://sepuplhs.org/high/sgi/teachers/fishery_sim.html to explore factors that influence population growth of a specific population - Avril gulf tuna. Compare to population growth of bacteria under different conditions. 3. Literacy task: Students practice making a focused claim (e.g., decrease in food supply decrease in pollution growth) and using graphs to list evidence of support of the claim)
hereditable genetic variation	***Sunflower seeds***:

	1. Framing: Ask students to take off a shoe and place in the middle of the room. Students try categorizing the "varieties" of shoes and then discuss "why" there is variation (e.g., preference, functionality, price).
	2. Students then pick seeds from a bowl, examined it closely, return it to the bowl, and tried to find it again to discuss general observations of variation in living things. Discuss how this variation arose (referring back to mutations in the genetics unit) and how hereditable genetic variation is key for change and is difference from non-heritable variation. Discuss variation in *S. aureus*, including antibiotic resistance.
	3. Literacy task: Students practice writing a simple causal chain of events to explain variation of sunflower seeds ("instructions in the DNA lead to proteins that code for sunflower structures. Every now and then a mutation changes instructions….") using common phrase that link ideas ("next, therefore, lead to, etc.)
competition	**Game "Oh Deer":** *1.* Framing: Prompt students to consider the benefits and consequences of using "hand sanitizer" - does it kill all bacteria? Students can read labels to uncover is different strains of *S. aureus* are harmed or not. *2.* Explore: Students engage in an outdoor simulation: ***where they*** pretended to be either a deer or a resource (water, food, shelter). Deer must procure resources to survive, competing against their classmates who are also deer – helping understand the factor of competition. Connection is made to competition between *S. aureus* and antibiotic resistant *S. aureus*. 3. Literacy task: Students practice outlining a defensible claim for "using hand sanitizer," including the difference between using scientific principles (completion between bacterial stains) vs. opinions to support a claim as well as considering different priorities (does offer protection from harmful bacteria).
differential reproductive success (survival of the fitter)	**Wormeater Simulation:** *1.* Framing: Students are asked to consider a petri dish of resistant and non-resistant bacteria competing – will the resistant bacteria always outreproduce and populate? 2. Explore: Students are given a utensil and have to "hunt" for worms (rubberbands) on the classroom floor. Survivors reproduce. After a certain number of generations a difference surface such as grass is used. Discuss data and how environment selects what variations are more fit and survive. 3. Literacy task: Students use the idea of environment changing to build on/refine defensible claim for using hand sanitizer.

[a]Adapted from Passmore, C., Coleman, E., Horton, J., & Parker, H. 2013. Making sense of natural selection. *The Science Teacher 80*(6): 43-49.

Part IV: Revising the Model (Day 8)

7. Hand students a summary graphic organizer (Figure 4) and give students (already situated in groups of 4) a number (1, 2, 3, or 4). Instruct each student to review the activity and notes associated with the assigned factor (e.g., 1 = population growth) and summarize the key points and pieces of evidence. Instruct students to then each summarize their factor and activity to the rest of the group, so that by the end each student has the graphic organizer completed. Instruct groups to write a summary sentence that attempts to connect all four factors.

Table 3. Natural Selection Jigsaw

1. population growth *(fish simulation)*	*2. hereditable genetic variation* *(sunflower seeds)*
3. Competition *(game: "Oh Deer")*	*4. Survival of the fitter* *(wormeater simulation)*

8. Display a word web (Figure 4) on the white or smart board. Ask one group to share key points and summary statement with the whole class. Use this as an opportunity to check for gaps in student understanding, particularly how the four factors form the foundation for the mechanism of natural selection.
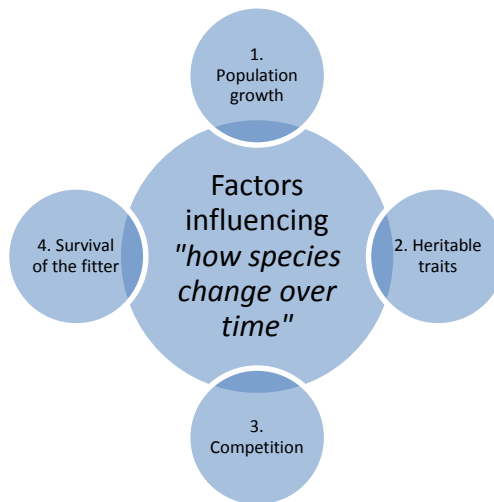

Figure 4. Word Web

9. Pass back students' initial outline (from day 1) and display a new table (Table 4) with new information about MRSA (when antibiotics were introduced). Remind students that "our goal is to use what we have learned these influential factors to explain our initial problem - how the species *Staphylococcus aureus* has changed so that over 60% are resistant to multiple antibiotics. In other words, "what causes this so called 'superbug' called MRSA?"

Table 4. Revised Antibiotic Resistance Timeline

Late 1880s	**1941**	**1959**	**1961**	**Present**

Staphylococcus aureus first identified by scientists	Penicillin available in the U.S. and England First resistant form of Staphylococcus aureus identified (resistant to penicillin)	Methicillin available in the U.S. and England	First case of MRSA reported (resistant to penicillin and methicillin)	Over 60% of Staphylococcus aureus is resistant to methicillin [MRSA])

10. Instruct students to revise (add/change/remove) their initial outlines based on what they have learned about natural selection and the new information presented in the timeline. Ask students to share their revised models in groups as peers (with sticky notes) provide feedback. Teachers can provide sentence frames to assist students in providing feedback, "We were wondering about [part of model] because _____."

Day 9

11. Explain to students that today they will turn your explanatory models (via the outline) into an actual written explanation that reflects the language that scientists use. They will also be supporting ideas with evidence, and communicating in a way targeted for a particular audience. Pass out three "Model Texts" (Appendices A, B, and C) and instruct students to (1) take out highlighter and pencil, (2) silently skim through the example texts, (3) highlight any concepts they think are important, and (4) circle any words they do not understand. Instruct students to share both important concepts and unknown words in their groups of 4. Students can answer questions about unknown words, and teachers can circulate through the class helping to clarify terms reminding students that as good readers we need to know "what we know" and "what we don't know."

12. Provide each group with a whiteboard, which they will use to make a graphic organizer as shown in Table 5.

Table 5. Reciprocal Reading Graphic Organizer

	New Answers to MRSA	Staphylococcus aureus Infections	MRSA Spreads in Households
Claim			
Evidence			
Audience			

Discuss the four reading roles below that you will provide to each group member. You might want to consider WHO you want in each role (in particular is this an opportunity for ELs to practice reading aloud?) Rotate roles after students read the first text.

1. *Reader (read the text aloud)* – after each paragraph check and see if your group understands the text.

2. *Claim finder* - as the text is being read, identify and record the claim of the text ("what is the major assertion or idea").

3. *Evidence finder* - as the text is being read, identify and record any evidence supporting the claim.

4. *Audience predictor* – at the end of the text, predict who the audience of this text might be. Record with a reason!

13. Facilitate a discussion comparing texts to help them recognize how information is communicated and what texts serve the purpose of using evidence and scientific principles to explain how something works or a causal effect (like how bacteria can change). In particular discuss general structures of an explanation (some claim, evidence used to support the claim, and statements that use evidence to account for what is happening, and thus link evidence to claim [i.e., reasoning]). They can also distinguish between the claims (addressing a general issue vs. research question), evidence (general information vs. data collected), and reasoning (use of actual scientific principles) in each text. Teachers might ask students if one text is "better" at communicating than the others. Before answering, discuss the audience/purpose of each text. Help them see that the structure should fit the particular audience (general public might need just general information, while another scientists or policy maker might need evidence drawn from actual data). Explain that our job is to use evidence from the various activities throughout the week and to provide a detailed account of what is happening (as opposed to general information).

14. Finish the day by discussing criteria that will guide student's own written explanations (Figure 5). Appendix D contains a detailed rubric for the culminating assessment, which can be modified as needed for the practice explanation context. The rubric looks at sense-making, use of evidence, and clarity and tone of writing across four levels

Your explanation will be evaluated on 3 criteria. How well you...

- demonstrate your understanding of **adaptation and natural selection** (include related concepts such as *population, genetic variation, competition, fitness, and environment*)

- support your explanation **with evidence** and connect evidence to the **process of natural selection**

- write a clear and cohesive explanation. Your writing should...
  - ✓ *connect* ideas through purposeful organization and transition words/phrases.
  - ✓ take a *formal tone* and use a *variety* of word/sentence structure choices.
  - ✓ *clearly communicate* ideas through standard writing conventions, including spelling, grammar, and sentence structure.

Figure 5. Criteria for Success

Day 10 (or Day 10 and 11)

15. Review the explanation objective "explain how the species *Staphylococcus aureus* changed so that over 60% are methicillin resistant" as well as rubric criteria and available resources (e.g., factors summary organizer). Figure 6 displays a graphic organizers that can be used to help students bridge from a visual sequence of events to a written explanation that also accounts for change over time. Students can also be prompted to outline the various explanation components firsrt (i.e., claim, evidence, reasoning). Provide time to write explanations individually. (If individual computers are available, they may type and share with others via google documents or other platform).

The diagram below is a **possible** representation of how bacteria change over time. In the boxes below, write down any words, concepts, or pictures that will help you explain what is happening over time.
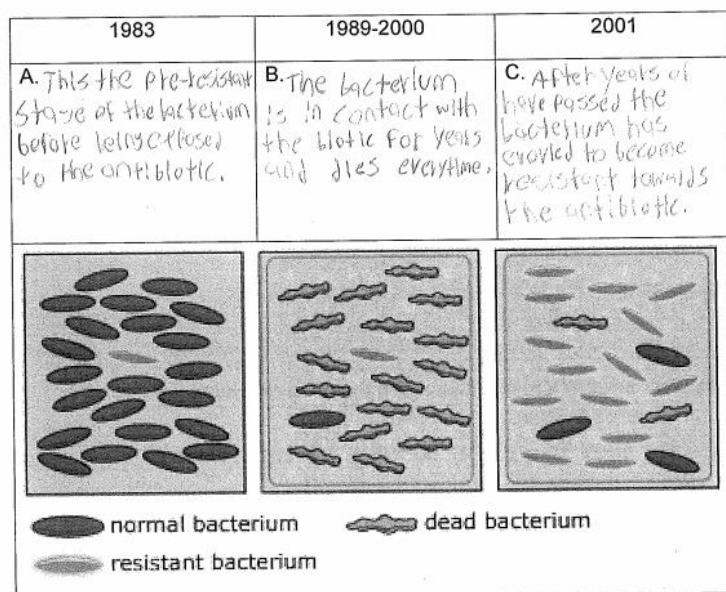
1983	1989-2000	2001
A. This the pre-resistant stage of the bacterium before being exposed to the antibiotic.	B. The bacterium is in contact with the biotic for years and dies everytime.	C. After years of have passed the bacterium has evolved to become resistant towards the antibiotic.

normal bacterium   dead bacterium

resistant bacterium

Figure 6. Student Response to Explanation Planning Exercise

16. Similar to the outlines, instruct students to switch and provide feedback on someone else's explanation, then instruct them to go back and revise.

17. Ask one or two students to share explanations (choose those that appear to exemplify a quality explanation) using a document camera or projector). Facilitate a class discussion about the explanation.

18. As closure, instruct students to describe how their thinking about how species change and bacterial infections has differed from when they started the unit. Give a brief answer to the very original question: Considering what you have experienced and know about hospitals, would someone be likely to get an infection (from bacteria) WHILE staying in a hospital?

Culminating Assessment, Extensions, and Cross-curricular Applications

After students have had ample opportunity and assistance in making sense of natural selection and developing disciplinary language and literacy through the phenomenon of antibiotic resistant bacteria, provide one final in class or at home task to find out how well students can transfer what they learned to a new context. Introduce a particular antibiotic, Vancomycin, which is often used to treat MRSA. However, describe how, like other antibiotics, bacteria can even be resistant to Vancomycin. Provide students with the new question and data (Figure 7) that can be used to support the explaining:

Resistance to the antibiotic Vancomycin rose dramatically over the 1990s in US hospital intensive care units.
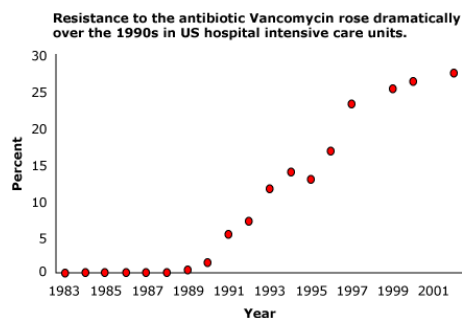
Figure 7. Data to Support Culminating Assessment Explanation

- Your job now is to apply your own understanding about adaptation and natural selection to explain **with evidence** how the percentage of bacteria resistant to Vancomycin changed from 1983 to 2001.

Review criteria again with students (Figure 5) and show/discuss sample student work representing high/low performance. The same planning graphic organizers may be used (Figure 6), depending on how proficient students are after the practice explanation. This is a potential way to differentiate assessment. A sample student response is provided in Figure 8.

Finally, the culminating assessment can be extended or augmented by providing a new, more contextualized audience, such as writing for a school newspaper or a local day care explaining the emergence of MRSA and pros/cons of antibiotic use. Teachers can provide additional articles that discuss concerns and "myths" about superbugs to supplement student letters. The activity can also be implemented along with parallel social science curriculum around the effect of diseases in societies.

Firstly, bacteria it is well known by now by the world and how it is everywhere and how easy it is to be infected by it leading to infections or diseases. Bacteria can change even evolve and that is a problem especially for the antibiotics used to fight them. A chart on the antibiotic vancomycin and bacteria showed that within

the years of 1990 to 2001 bacteria had aquilled a neat 30 percent resistance to the antibiotic. This is their adaption of years exposed to the antibiotic as natural selection can explain. Natural selection is another term for survival of the fittest, in which one mustevolve to survive. It's seen in any organism that competes for survival as their evolving their new traits or features improve their overall fitness that is needed to survive. This logic applies to bacteria, they become resistant to our antiliotics so they can survive.

Bacteria will continue to resistant our antiliotics to survive, that's just nature. We can continue to make our antibiotics stronger to fight, but its a costly endeavor. The bacteria will be an evergrowing threat as evove to resist our best antibiotics and force us to implore our efforts. Natural Selection is an never ending struggle for good reasons, but it's neccesary for all living things to grow and learn.

Figure 8. Student Response to Culminating Explanation

Discussion: Supporting ELs during the Antibiotic Resistance of MRSA

A key aspect of the Antibiotic Resistance of MRSA is *simultaneously* (1) developing students' understanding of natural selection and (2) disciplinary-literacy (as opposed to treating these as separate domains). For ELs, this integrated approach allows them to increase English proficiency in reading, writing, listening, and speaking by placing language use in a context that is both meaningful and relevant to students. ELs have multiple modes of representation and thinking to use language, and can practice interpreting and producing discipline-specific uses of language. Carlos, whose worked is displayed in Figure 8 is an advanced EL in a high school biology class. Each of the four SSTELLA practices may contribute to helping EL make sense of natural selection and develop the ability the write a scientific explanation that attends to discourse norms and writing conventions/style/tone.

Contextualize Science Activity. The activity frames natural selection through a real world context – the "superbug" MRSA, which despite the benefit of antibiotics can arise through overuse. Of particular note, MRSA is not used as just a "hook" just at the start of a lesson. The entire unit is designed so that students are learning science and engaging in investigations to address the question posed to them.

Moreover, the opening anticipatory question is an example of how to elicit students' lived experiences and help them see the connection between the problem, what they will be learning, and their own lives. Carlos will have the opportunity to consider and use language in a context more similar to his own experiences and that is shared from his peers. For instance, "hand sanitizers" might be something he is familiar with and this knowledge can be leveraged for further understanding. In his response, Carlos continues to situate the notion of antibiotic resistance in a real-world context: "Bacteria will continue to resistant [sic] our antibiotics…"

Promote scientific sense-making through scientific/engineering practices. Through the entire unit, students are making sense of natural selection by developing an explanatory model to represent the process in the context of MRSA. The key for ELs is to bridge everyday ways of knowing and using language with the specific ideas (and language associated with those ideas) being taught. First, students are introduced to the phenomenon (emergence of superbugs) as they organize what they already know about major players (e.g., bacteria, antibiotics, etc.) and develop the initial model. The initial model provides a change to use language in a variety of ways, other than written or oral form. At that stage, students might begin noting what they "don't know" (e.g., what role might antibiotics play in the process? How do individual bacteria acquire resistance?). The idea is to start bridging how they might explain and provide evidence with the accepted explanation. The graphic organizers in Figure X continue to allow ELs to connect visual representations with words/phrases learned throughout instruction and continue bridging ways of knowing and explaining. Carlos used the phrases "pre-resistance," "in contact with" and "become resistant," which can serve to convey ideas in his explanations and internally make sense of the visual, which depicts natural selectin within bacteria. During instruction, students then engage in activities that allow them to make sense of factors influencing how species change over time (instead of being told the factors directly). More importantly, students then distribute their expertise and share summaries of each factor via the jigsaw, before trying to synthesize the factors (ultimately pieces together inferences that comprise the mechanism of natural selection). The students then engage in a revision of the model, now having a deeper conceptual understanding of natural selection, before finally communicating their explanatory model via a written explanation. Carlos displays some understanding of natural selection, connecting ideas that organisms "compete for survival" and "new traits or features improve their overall fitness." What often is missing from student explanation, including students completing this culminating assessment, is a description of the ultimate source of variation. Instead, students might consider individual bacteria as changing, instead of the proportion within a population as changing. Nevertheless, ELs are benefiting from the rigor of connecting ideas, which involve even greater uses of language, rather than espousing definitions and simple descriptions as evidence of learning.

Promote scientific discourse: Both the NGSS and CCSS focus on the discourse of explanation. By reading and discussing the two explanation texts, students have the opportunity to unpack the structure of explanations, including claims, evidence, and reasoning and incorporate those forms into their final explanations as a way to communicate information. Carlos asserts that "bacteria can change even evolve." He interprets the graph provided, noting the actual change in percentage from 1990 to 2001. He then accounts for the data through changes in the environment, in particular the introduction of antibiotics. The explanation structure and particular use of evidence bridged Carlos' sense-making around natural selection with disciplinary-literacy: knowing what counts as evidence, how to refer to data, and how to connect evidence with scientific principles and claims being made. For example, "a chart on the antibiotic…showed…" Making an explicit reference to the chart is just one particular discursive move that once again increases the range of language Carlos can use.

Promote English Language and Disciplinary-Literacy Development. Finally, students have multiple opportunities to develop disciplinary-literacy. They engage in reciprocal reading to comprehend texts and identify audience/purpose. This reading itself provides models for their own written explanations. They get targeted feedback from their peers, a rubric to guide their writing, and feedback from the teacher by discussing a student's explanation with the whole class. Carlos still misspells words

and uses improper writing conventions "continue to resistant." However, Carlos does employ a clear organization to his explanation. He provides an introductory section about the issue, asserts that bacteria change, provide evidence, using natural selection to account for the data, and finishes with a concluding section that revisits the issue once again. Throughout the unit, the focus is on communicating ideas clearly to a particular audience. While writing conventions contribute to clarity of ideas, they are not the primary focus of disciplinary literacy development. Finally, Carlos has been given opportunities to comprehend vocabulary (e.g., antibiotic, resistance, competition, fitness, bacteria) and use them while engaging in the scientific practice of explaining, instead of just being expected to recall vocabulary definitions. Many of these terms have disciplinary specific meanings (e.g., resistance as protection rather than as standing up to an organization) and ELs can begin distinguishing between different uses of terms.

In conclusion, it is imperative to consider an *integrated* approach to language, literacy, and science, when considering science activities that include literacy tasks. *The Antibiotic Resistance of MRSA*, exemplifies how science teachers can facilitate students' sense-making of evolution by natural selection, through contextualized, real-world issues while *simultaneously* helping students develop disciplinary literacy.

Endnotes

[1] Since the unit focuses on bacteria, it should be communicated to students that although bacteria do not undergo sexual reproduction, bacteria conjugation can be another source of variation.

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Appendix A: "New answer to MRSA, other 'superbug' infections: clay minerals?[1]"

Researchers discover natural clay deposits with antibacterial properties

*Are the best medicines hidden in the Earth? French green
clays are used for healing Buruli ulcers.*
<u>*Credit and Larger Version*</u>

Superbugs, they're called: Pathogens, or disease-causing microorganisms, resistant to multiple antibiotics.

Such antibiotic resistance is now a major public health concern.

"This serious threat is no longer a prediction for the future," states a 2014 World Health Organization report, "it's happening right now in every region of the world and has the potential to affect anyone, of any age, in any country."

Could the answer to this threat be hidden in clays formed in minerals deep in the Earth?

Biomedicine meets geochemistry

"As antibiotic-resistant bacterial strains emerge and pose increasing health risks," says Lynda Williams, a biogeochemist at Arizona State University (ASU), "new antibacterial agents are urgently needed."

To find answers, Williams and colleague Keith Morrison of ASU set out to identify naturally-occurring antibacterial clays effective at killing antibiotic-resistant bacteria.

The scientists headed to the field--the rock field. In a volcanic deposit near Crater Lake, Oregon, they hit pay dirt.

Back in the lab, the researchers incubated the pathogens *Escherichia coli* and *Staphylococcus epidermidis,* which breeds skin infections, with clays from different zones of the Oregon deposit.

They found that the clays' rapid uptake of iron impaired bacterial metabolism. Cells were flooded with excess iron, which overwhelmed iron storage proteins and killed the bacteria.

"The ability of antibacterial clays to buffer pH also appears key to their healing potential and viability as alternatives to conventional antibiotics," state the scientists in a paper recently published in the journal *Environmental Geochemistry and Health*.

"Minerals have long had a role in non-traditional medicine," says Enriqueta Barrera, a program director in the National Science Foundation's (NSF) Division of Earth Sciences, which funded the research.

"Yet there is often no understanding of the reaction between the minerals and the human body or agents that cause illness. This research explains the mechanism by which clay minerals interfere with the functioning of pathogenic bacteria. The results have the potential to lead to the wide use of clays in the pharmaceutical industry."

[1]From National Science Foundation (July 17, 2014)
http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=132052&WT.mc_id=USNSF_51&WT.mc_ev=click

Appendix B: "Staphylococcus aureus Infections[1]"

Staphylococcus aureus *is the most dangerous of all of the many common staphylococcal bacteria.*

These bacteria are spread by having direct contact with an infected person, by using a contaminated object, or by inhaling infected droplets dispersed by sneezing or coughing.

- Skin infections are common, but the bacteria can spread through the bloodstream and infect distant organs.
- Skin infections may cause blisters, abscesses, and redness and swelling in the infected area.
- The diagnosis is based on the appearance of the skin or identification of the bacteria in a sample of the infected material.
- Thoroughly washing the hands can help prevent spread of infection.
- Antibiotics are chosen based on whether they are likely to be effective against the strain causing the infection.

Staphylococcus aureus is present in the nose of adults (temporarily in 60% and permanently in 20 to 30%) and sometimes on the skin. People who have the bacteria but do not have any symptoms caused by the bacteria are called carriers. People most likely to be carriers include those whose skin is repeatedly punctured or broken, such as the following:

- People who have diabetes mellitus and have to regularly inject insulin
- People who inject illegal drugs
- People who are being treated with hemodialysis or chronic ambulatory peritoneal dialysis
- People with skin infections, AIDS, or previous staphylococcal bloodstream infections

People can move the bacteria from their nose to other body parts with their hands, sometimes leading to infection. Carriers can develop infection if they have surgery, are treated with hemodialysis or chronic ambulatory peritoneal dialysis, or have AIDS.

The bacteria can spread from person to person by direct contact, through contaminated objects (such as telephones, door knobs, television remote controls, or elevator buttons), or, less often, by inhalation of infected droplets dispersed by sneezing or coughing.

Methicillin-Resistant Staphylococcus aureus (MRSA):

Because antibiotics are widely used in hospitals, hospital staff members commonly carry resistant strains. When people are infected in a health care facility, the bacteria are usually resistant to several types of antibiotics, including all antibiotics that are related to penicillin (called beta-lactam antibiotics). Strains of bacteria that are resistant to beta-lactam antibiotics are called methicillin-resistant*Staphylococcus aureus* (MRSA). MRSA strains are common if infection is acquired in a health care facility, and more and more infections acquired in the community, including mild abscesses and skin infections, are caused by MRSA strains

[1]Adapted from
http://www.merckmanuals.com/home/infections/bacterial_infections/staphylococcus_aureus_infections.html
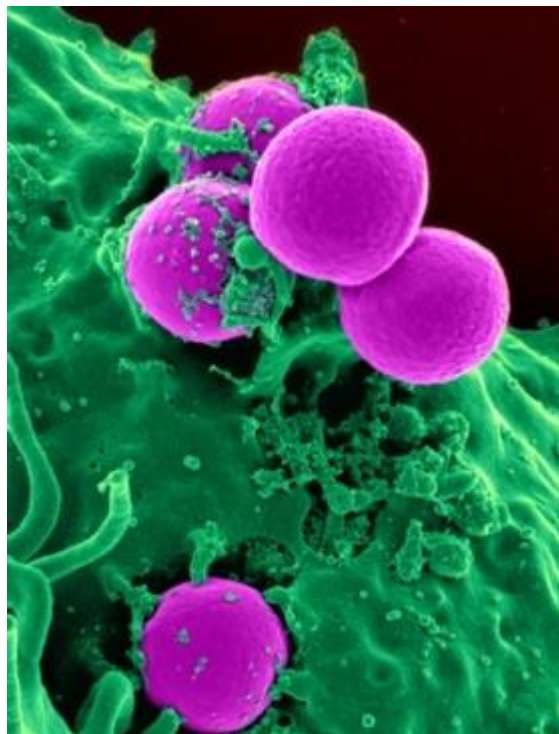
Appendix C

Text 3: "MRSA Spreads in Households"

http://www.scientificamerican.com/article/mrsa-spreads-in-households/

MRSA Spreads in Households

Drug-resistant bacteria have found refuge in residences in parts of New York City

nature

April 22, 2014 |By Jyoti Madhusoodanan and Nature magazine

MRSA bacteria (pink) of various types were found in New York households.
Credit: NIAID

Genome sequencing has revealed how a strain of methicillin-resistant *Staphylococcus aureus* (MRSA) spread through parts of New York City. Although MRSA is often associated with public spaces such as hospital and gyms, researchers say that private homes helped to fuel its travels in the New York neighborhoods of Manhattan and the Bronx.

The study, published in the *Proceedings of the National Academy of Sciences*, suggests a framework for other investigations into how pathogens colonize and infect communities. Researchers examined the prevalence of the USA300 strain in northern Manhattan and the Bronx, where it has caused an epidemic of skin and soft-tissue infections in recent years. In 2009, it was responsible for around 75% of community-acquired MRSA infections in northern Manhattan.

Anne-Catrin Uhlemann, a microbiologist at Columbia University Medical Center in New York, and her colleagues sequenced the genomes of 400 samples of MRSA collected from 161 people between 2009 and 2011, and compared them with samples from healthy people (many healthy people carry *S. aureus* bacteria, which could be MRSA). They also gathered data on study participants' medical histories, antibiotic use and home locations to identify a network of USA300 transmission.

"This is an elegant and productive use of whole-genome sequencing in an epidemiological investigation," says microbiologist Alexander Tomasz of the Rockefeller University in New York.

Evolving infection

Uhlemann and her team estimated the similarity between MRSA samples by checking how many different single-nucleotide polymorphisms (SNPs) — single-letter changes in their genomes — they had, and working out how fast these changes accumulated. The

researchers calculated that the USA300 strains diverged from their most recent common ancestor around 1993. Although 85% of the samples were closely related to two known reference USA300 genomes, others were more diverse.
The team found that some of the samples originated in California and Texas, suggesting that USA300 was introduced into New York multiple times, rather than having one local ancestor.

Samples from people in a single household tended to be more similar to each other than to samples from other households, which implies that individuals within a home frequently exchange *S. aureus*. But people were also getting infected outside the home: "There were some households where we found multiple kinds of USA300, which is quite surprising," says Uhlemann. "It suggests some kind of outside reservoir, such as a link to a hospital or a gym."It seems that the USA300 strain spread in public spaces first, but it is now prevalent in households as well as hospitals. Further studies are needed to evaluate how hospitals might be involved in spreading the bacteria back into the community, say the study authors.
Uhlemann and her colleagues also found that nearly two-thirds of their bacterial samples were either fully or partially resistant to fluoroquinolone antibiotics, which are often prescribed for routine bacterial infections. The drug gets excreted onto skin surfaces, which the authors suggest may have contributed to the resistance in USA300: the bacteria get exposed to low levels of the antibiotic and can evolve ways to survive it. "We have to limit our antibiotic use because the consequences may really be a lot of collateral damage," says Uhlemann.
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APPENDIX D: CULMINATING ASSESSMENT RUBRIC

	Level 1	Level 2	Level 3	Level 4
Sense-making	*No/limited understanding of natural selection*: Able to state discrete, factual information about natural selection at best.	*Incomplete or alternative understanding of natural selection.* Able to accurately describe at least one factors contributing to natural selection, but without connecting any factor OR Able to provide at least a logical *partial* chain of events, but through an alternative conception of natural selection.	*Partial understanding and application of natural selection*: Able to use factor contributing to natural selection to provide *part* of a logical and accurate partial chain of events.	*Full understanding and application of natural selection*: Able to use factors contributing to natural selection to provide a *complete and accurate,* chain of events.
Use of Evidence	*No use of evidence:* No attempt to use any form of evidence	*Limited/inappropriate use of evidence:* EITHER Refers to data/general trends in the graph w/o any interpretation (e.g., resistant bacteria increased) OR refers to data/general trends in the graph, but misinterprets data OR Interprets a general trend across the whole timeline in the graph generally w/o actual data	*Partially linked evidence:* Interprets some data from the graph. May be done through actual numbers/trends.Links data as evidence to support EITHER an identifiable claim OR contributing factors to natural selection (e.g., during 1990s, *resistance to antibiotics* increased	*Fully linked evidence:* Interprets ENTIRE data from the graph appropriately through actual numbers/trends. Links data as evidence to support an identifiable claim as well as contributing factors to natural selection
Clarity and Tone of Writing	*Ideas in the response are difficult to understand due to two or more of the following categories*: CATEGORY 1 (RELEVANCE): Ideas are not related or only loosely related to the prompt. CATEGORY 2 (TONE and STYLE): Multiple subjective/ colloquial constructions used AND repetitive word/phrase/sentence structure used throughout CATEGORY 3 (RELATIONSHIP BETWEEN IDEAS): Lacks Transition devices, an introductory sentence, and a concluding sentence. Some ambiguous Pronouns CATEGORY 4 (WRITING CONVENTIONS): Multiple instances of Sentence fragments, Run-on sentences, Lack of/improper punctuation, or Spelling errors	*Ideas are understandable but some assumptions have to be made due to two or more of the following categories*: CATEGORY 1 (RELEVANCE): Ideas are related to the prompt with minor tangential or unrelated parts. CATEGORY 2 (TONE and STYLE): Mostly objective language used throughout (specific data/evidence not opinion) OR repetitive word/phrase/sentence structure used throughout CATEGORY 3 (RELATIONSHIP BETWEEN IDEAS): Lacks Transition devices, an introductory sentence, and a concluding sentence. Some ambiguous Pronouns CATEGORY 4 (WRITING CONVENTIONS): Multiple instances of Sentence fragments, Run-on sentences, Lack of/improper punctuation, or Spelling errors	*Ideas are clearly communicated. Meets all categories*: CATEGORY 1 (RELEVANCE): Ideas are related to the prompt. CATEGORY 2 (TONE and STYLE): At least mostly objective language used throughout (specific data/evidence not opinion) AND only a couple instances of repetitious word/ phrase/sentence structure CATEGORY 3 (RELATIONSHIP BETWEEN IDEAS): At least 1 Transition Device String: First, Second, Third or To start, Next, Finally or One, Another, Last OR Single Instance: Also, Last(ly) CATEGORY 4 (WRITING CONVENTIONS): Contains Complete Sentences with (minimum): Subject and predicate, beginning capitalization, and ending punctuation May contain: Minor mechanics errors (spelling – can decipher the word – and/or punctuation)	*Ideas are clearly communicated AND stylistically advanced. Meets all categories*: CATEGORY 1 (RELEVANCE): Ideas are related to the prompt. CATEGORY 2 (TONE and STYLE): Exclusively objective language used throughout (specific data/evidence not opinion) AND varied used of words/phrases/sentence structure CATEGORY 3 (RELATIONSHIP BETWEEN IDEAS): Contains a separate Introductory Sentence, Multiple Transition Devices, AND a separate Concluding Sentence CATEGORY 4 (WRITING CONVENTIONS): Contains Complete Sentences (see level 3). May contain: Minor mechanics errors