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Antibiotic Resistance

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Introduction to the Teacher

Timeline and Discipline	Big Idea and Essential Questions	Lesson Overview	Eliciting and Engaging the Student	Developing the Ideas	Checking for Understanding
<p><u>Timeline:</u> ~1 day <u>Discipline:</u> Any</p>	<p>BIG IDEA 1: How the case study may be different than what students are used to and what the expectations are.</p> <p><u>Essential Questions:</u></p> <ol style="list-style-type: none"> 1. How does the case study differ from what I (a student) may be used to in the classroom? 2. What will I (a student) be expected to do? 3. How and why do people work in teams? 	<p>In these three lessons students are introduced to the case study approach.</p> <p>Lesson 1-1 asks students to discuss how they prefer to learn. Lesson 1-2 is a description of the what the students should expect. Lesson 1-3 is a discussion the challenges, strategies, and benefits of working in teams.</p>	<p>Lesson 1-1: Introduction to learning styles</p> <p>Lesson 1-2: Expectations for the case study</p> <p>Lesson 1-3: Working in teams</p>		<p>Ask the Questions:</p> <ol style="list-style-type: none"> 1. What concerns do you have about the upcoming case study? What are you excited about? 2. Have you worked in teams before? What was it like?
<p><u>Timeline:</u> ~1 day <u>Discipline:</u> Science</p>	<p>Inception BIG IDEA 2: Antibiotic resistance has a major impact on modern medicine.</p> <p><u>Essential Questions:</u></p> <ol style="list-style-type: none"> 1. What is the impact of antibiotic resistance on 	<p>In these lessons, students are introduced to the topic of the case study and become invested in it.</p> <p>Students are polled on antibiotic</p>	<p>Lesson 2-1: Polling the students</p> <p>Lesson 2-2: Inception video</p>		<p>Ask the question:</p> <ol style="list-style-type: none"> 1. Who does antibiotic resistance impact?

	our society and how we treat infections?	resistance and watch an inception video on a superbug.			
<p><u>Timeline:</u> ~2 days</p> <p><u>Discipline:</u> Environmental Studies, Science</p>	<p>Engagement <u>BIG IDEA 3:</u> Defining antibiotic resistance</p> <p><u>Essential Questions:</u></p> <ol style="list-style-type: none"> 1. What is antibiotic resistance? 2. Will the resistant bacteria spread through the population? 3. Why do we use antibiotics so frequently? 	<p>Through these lessons students become engaged in the topic of antibiotic resistance.</p> <p>Students will discuss the question of if colistin can still be used as a last-resort antibiotic, and will create a class list discussing the engagement question. Each team will pick a solution to antibiotic resistance.</p>		<p>Lesson 3-1: Engagement Question and Antibiotic Resistance Lecture</p> <p>Lesson 3-2: Topic Exploration</p>	<p>Ask the question:</p> <ol style="list-style-type: none"> 1. List the pros and cons of three different solutions to the resistance of E. coli to colistin.
<p><u>Timeline:</u> ~1 week</p> <p><u>Discipline:</u> Science</p>	<p>Research <u>BIG IDEA 4:</u> Scientific inquiry skills can be used to address antibiotic resistance</p> <p><u>Essential Questions:</u></p>	<p>In these lessons, students collect background information on their topic, write a research question, and collect data</p>	<p>Lesson 4-1: Topic diagram</p> <p>Lesson 4-3: Form a hypothesis</p> <p>Lesson 4-4:</p>	<p>Lesson 4-2: Writing a research question</p> <p>Lesson 4-5: Conducting the research</p>	<p>Discuss with each team whether they have gathered enough information to answer their research question. Do they have the</p>

	<ol style="list-style-type: none"> 1. What is known about this topic? What is not known? 2. How do you write a research question? 3. How should I collect my information? 4. Which sources are reliable and reputable? 	and information to answer their research question.	Designing the study		evidence to support their position? Are they missing a piece of information?
<p><u>Time:</u> ~1-2 days</p> <p><u>Discipline:</u> Science,</p>	<p>Create</p> <p>BIG IDEA 5: Scientific communication can be used to address antibiotic resistance</p> <p><u>Essential Questions:</u></p> <ol style="list-style-type: none"> 1. How do you draw conclusions from research and data? 2. Who would benefit most from hearing your conclusion? 3. How do you articulate your conclusion clearly and scientifically? 4. How could your research impact antibiotic resistance? 	In these lessons, students will draw a conclusion based on their research, communicate their conclusion to an audience outside the classroom, and present their team's project to the class.	Lesson 5-1: Drawing a conclusion	<p>Lesson 5-2: Communicating your findings</p> <p>Lesson 5-3: Peer-editing</p> <p>Lesson 5-4: Presenting</p>	<p>Ask the following questions:</p> <p>Compare and contrast yours and your classmates communication pieces. What do you think these communication pieces will accomplish?</p>
<p><u>Time:</u> ~1 day</p> <p><u>Discipline:</u> Any</p>	<p>Reflect</p> <p>BIG IDEA 6: Reflection is a tool for improving your scientific inquiry</p>	In this lesson students will reflect on their process recognize their	Lesson 6-1: Reflect		N/A

	<p>skills and for identifying the next steps for addressing antibiotic resistance</p> <p><u>Essential Questions:</u></p> <ol style="list-style-type: none">1. What have I learned?2. What have I done well?3. How can I improve?	<p>strengths, their opportunities for growth, and what they have learned and accomplished.</p>			
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Introduction to Teacher

Case studies are a student-driven, situation-based approach to learning science. Students investigate a societal problem through asking questions, researching, drawing conclusions, and communicating their findings. This case study addresses Antibiotic Resistance. Antibiotic resistance refers to the ability for infectious microbes to acquire genes for resistance to antibiotic drugs. Students are introduced to this topic through a report on a strain of *E. coli* found in the US and resistant to a last resort antibiotic. Later, student teams choose a solution to antibiotic resistance to research further. By the end of the case study each team will have moved the needle forward on antibiotic resistance as it relates to public health.

This high-school level case study is adapted from a college-level science program called the Integrated Concentration in Science (iCons) Program at University of Massachusetts Amherst. Students in this program bring their expertise from a variety of science and engineering majors and work together on interdisciplinary societal problems in the fields of renewable energy and biomedicine. To learn more about the iCons program, you can visit our [website](#).

The case study method, which hopes to engage scientific curiosity and inquiry, works in conjunction with lecture style learning in which students focus mainly on basic scientific principles and their significance. The goals of the case study method are focused just as much on the skills students develop from the experience of self-driven learning as they are on the facts they learn. This may be a shift from the students' normal experiences, so it is important to emphasize the value of the learning process before you begin. Then you may proceed through the five steps of the iCons Case Study learning process: inception, engagement, research, create, and reflect.

Inception is the first step in the iCons case study method. The purpose of this step is to introduce the topic of the case study and get the students invested in it. An effective inception material draws attention to a particular time and place, brings relevancy to the societal issue, and leads students into the engagement step.

The **Engagement** step allows students to “buy in” to the case study curriculum before they begin the highly student-driven Research step. The Engagement step is when students become aware of how scientific inquiry will help them address the societal issue. They will gain confidence and motivation to address this societal problem and become curious about the scientific phenomena underlying the societal issue.

The **Research** step requires students to narrow their topic. Teams are challenged to understand one topic completely in order to answer a specific research question and to eventually draw original conclusions. Students have the freedom to conduct an experiment, compile information from other scientists' findings, survey other's understanding and habits, calculate a cost-benefit analysis of a certain object/practice, etc. or a combination of these in

order to answer their research question. It is important to give students freedom and to push them to do their best work so that they can exceed their own expectations of what they can accomplish.

In the **Create** step, the students communicate the conclusions they have drawn from their research to an audience outside the classroom and to their peers. This grounds the students' work in reality and reinforces the idea that their work is important, valid, and applicable to a real issue. Students then present their whole research process and communication product to the class.

The **Reflection** step is for students to analyze, critique, and evaluate their process and product, and recognize how they have learned and grown through the case study. It is also a data-collection tool to inform improvements of your case study curriculum design. Students will incorporate feedback from others and draw from their own experiences to answer reflection questions. Reflection questions should cover personal growth, team dynamics, engagement, and societal impact of their research.

Journal Check-in: These optional check-ins are interspersed throughout the case study in places we feel students would benefit from collecting their thoughts and setting goals. They are meant to be 3-5 minute reflection periods during which students respond in journals to prompts related to the previous activity. The purpose of these journal activities is to help students prepare for the reflection step of the case study, process their experiences in this new and possibly uncomfortable learning style, and become self-reflective learners.

The following Next Generation Science Standards can be addressed in this case study:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-LS4-2. 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, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

*HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

*HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

*HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

*HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

*These standards may be addressed depending on what students choose to investigate for their research and create steps.

During case study days, students work in teams to address the issue of antibiotic resistance through scientific research. Students develop research and collaboration skills throughout the process; therefore, it is not just the final product that can be used as an assessment for learning, personal growth, and team collaboration. Student participation and cooperation are required throughout, and they may need periodic feedback to guide their level of efficiency. This is different from traditional-style curriculum, in which assessment tools like tests and exams are often used to measure individual growth.

In terms of timing, this case study could take a few different forms, depending on the format and schedule of your class. This could be done in a 2-3 week stretch where the case study is the only material being addressed during this time. Another option is for the case study to be interspersed with the regular curriculum two or three days a week for multiple weeks. This is up to your discretion concerning your class structure, student preference and curriculum layout. In addition, depending on the experience and academic level of your class, you may choose to add, edit, or remove activities to this lesson plan to meet the needs of your students. It is our hope that each teacher who uses these case studies makes them their own.

This curriculum was created by Dominique Kiki Carey, Rebecca Howard, Erica Light, Corrine Losch, and Stephanie Purington. We are members of the iCons community at the University of Massachusetts Amherst. This case study was developed based on our experiences teaching case studies in high-school classes. It has been revised to reflect all that we learned through our teaching, and we have incorporated suggestions into the teaching plans. From our experiences, we believe student-centered, case study-based education is an extremely effective and engaging way to learn. We hope to prepare students to be leaders in solving the world's challenges through research and critical thinking.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. National Academies Press.

Lesson 1-1: Introduction to learning styles

~20 minutes

Student Version	Teacher Discussion Notes	Materials
Syllabus	<p>Engage students in a discussion about how they learn best. We found that, at first, students had difficulty identifying approaches to learning that were effective for them. If this is the case, allow them time to talk to the person next to them about this topic and then return to the class discussion.</p> <p>We have seen classes come up with a list similar to this:</p> <ul style="list-style-type: none">● Hands-on activities● Group learning● Visual● Student-driven● Real-world context <p>Explain to students that the case study method that you will be using strives to incorporate many of these approaches. If students come up with learning approaches indicative of a lecture, explain that these approaches are valuable but not the focus of the case study method. While lecture-based lessons are useful for teaching concepts, vocabulary, and formulas, case studies allow students to explore personally-relevant topics and develop different analytical skills. Hand out the syllabus for the case study. Outline the learning goals and the five steps of the case study process.</p> <p>Give a general timeline of what they will be doing during the case study and deadlines that have been set. Be sure to inform your students that by the end of the case study they will have completed original research, a communication piece that will be sent outside the classroom, and a presentation.</p>	<p>Syllabus with timeline and learning goals</p>

Welcome to iCons Case Study!
“The whole is greater than the sum of its parts”
--Aristotle

What is iCons?

iCons (Integrated Concentration in Science) is a college-level science program that takes a new approach to teaching and learning science. This approach emphasizes student **engagement** through **collaboration**, active assignments, mentorship, and **real-world application**. It is impossible to learn everything you need to succeed in your career during high school since the world is rapidly changing around us. However, the iCons approach develops **thinking and reasoning** skills that are applicable to whatever you face in your future.

Learning Goals

- Collaborate in groups and use each student’s strengths to solve complex problems.
- Apply scientific thought to topics of personal interest.
- Develop confidence in your ability to think scientifically.
- Use scientific principles and concepts, experimentation, and analytical reasoning to understand, explain, and solve real-world problems.
- Accurately assess your own abilities, contributions, work, learning processes, and opportunities for growth.

Learning skills

- Formulate a research question.
- Identify reliable sources and use them to gather relevant information.
- Recognize the limits of valid conclusions, i.e. a study about one city may not apply to another.
- Effectively communicate scientific process, questions, findings, and application.
- Give and receive constructive criticism and feedback.

What are we doing?

This case study will focus on the issues surrounding **antibiotic resistance**, on the individual, community, and global level. Using your knowledge and research skills, you will study a piece of this societal problem and propose your own solution using the iCons case study approach outlined below.

1. Inception→ Get background information and connect with the topic
2. Engagement→ Get a deeper understanding. Identify what you know and questions you still have.
3. Research→ Find or produce data to answer a question.
4. Create→ Draw conclusions and create a product to communicate a new understanding.
5. Reflect→ Look back on work and identify areas of strength and opportunities for growth.

Lesson 1-2: Expectations for the case study
~20 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>Describe to your students how your expectations for the case study differ from some of your previous expectations in class. They will not be tested during the case study, but will demonstrate their learning through participation, effort, curiosity, critical thinking and teamwork. During this time, students will be expected to do original research around a research question that they will choose. The final product of this case study will be a product that reports their findings to a broader audience, such as a newspaper or public official. Students may be unfamiliar with their work having a broader audience than their teacher. If this is the case, be sure to articulate that their products do not merely have a theoretical audience.</p> <p>Students will be pushed to work in ways that are not necessarily comfortable for them initially, but this is an important step of the process in which much learning takes place. We encourage you to convey that this case study is a growth opportunity for students. This means that the grade for this case study will not only be on the product, but on the process and effort that the students demonstrate.</p>	N/A

Lesson 1-3: Working in teams

~20 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>Tell your students that they will be working in teams, and open up a discussion about challenges they may face, strategies to overcome challenges, and the value of teamwork. Give the students an opportunity to brainstorm solutions to anticipated challenges.</p> <p>From our experience, the biggest challenge students faced was a teammate who did not participate. Brainstorming solutions and strategies at the beginning of the case study may allow students to work more effectively in teams and avoid some strife. Be sure to review strategies like delegation and assignment of roles. This discussion may be more necessary in classes with less experience working in teams.</p>	N/A

Lesson 2-1: Polling the students' knowledge
~20 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>For your own knowledge, poll the class to gauge student understanding of antibiotic resistance.</p> <ul style="list-style-type: none">• You may find that many of them don't have a comprehensive grasp of antibiotic resistance and may carry with them misconceptions. Don't worry. In the engagement step, students will have the opportunity to gain more background knowledge and to have their misconceptions addressed.• You may want to alter this quiz based on your knowledge of the class's experience with this topic and/or use this quiz again after the engagement step to assess their growth. This pre-quiz should not be counted as a grade now, but the post-quiz could be graded.	Student Poll

Antibiotic Resistance Student Poll Answer Key

1. What is a bacteria?

- a. A contagious disease that results when you don't wash your hands or when you're with someone else who is sick
- b. A protein-capsule pathogen that inserts genetic material into your cells to reproduce
- c. A variety of unicellular organisms that cover almost every surface on earth and have both positive and negative impacts on other living things
- d. Single-celled organisms that produce molds on breads and cheeses

2. What are antibiotics used for?

Antibiotics are used to kill bacteria. Often they are prescribed when an infection is making people sick. They are also given to livestock to prevent them from getting sick and to promote growth.

3. How does an antibiotic work?

Antibiotics target structures in bacterial cells that are not found in human cells. They impair these structures causing the death of the bacteria, but not of human cells.

4. What is a gene?

A gene is a segment of DNA or RNA that codes for a certain protein that has a certain function or appearance. Genes proscribe the structures that make up living things.

5. What two ways do bacteria transfer genes to other bacteria?

Through inheritance-- bacteria reproduce by binary fission. Each cell duplicates its DNA and then divides in two.

Through conjugation-- bacteria form pili (a protein structure in the shape of a tube) connecting to another bacterium and exchange DNA without reproducing. This exchange can happen between bacteria of the same or different species.

6. What do you know about antibiotic resistance?

Answers may vary.

Lesson 2-2 Inception video

~20 minutes

Student Version	Teacher Discussion Notes	Materials
Video	Show the 4 minute video about a superbug. Begin a discussion with your students about what antibiotic resistance might mean for our society.	Internet and projector

Lesson 3-1: Engagement Question

Time	Engaging the Student (entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~45 minutes	<p>1. Break students into teams of 3 or 4. We recommend that you decide between random or assigned teams. You may want to put students into teams that balance their skills, interests, and abilities to work together, therefore encouraging positive team dynamics.</p> <p>2. Pose to teams the Engagement</p>	<p>Solutions Worksheet</p>	<p>This question is intentionally arguable from both perspectives. The point of asking this question is to get students thinking about when antibiotics are a valid option, when they are not, and solutions to slow antibiotic resistance.</p> <p>Allow students to discuss in teams and then report their team consensus back to the entire class. Discuss and write their evidence to the engagement question on the board. Have the students categorize the evidence listed on the board into “yes”, “no”, and “further questions” categories.</p> <p>Anticipated answers to this question include: Yes: Only one person had the disease in the US. CDC prevents the spread of disease. Antibiotics still work on most infections. There is not one bacteria resistant to them all yet.</p> <p>No: Diseases spread quickly. Each infected person can spread resistance genes to bacteria in multiple people. It has spread to the US. The gene for resistance can spread to other bacteria. The more we use them the more cases of resistance will form</p>	<p>Students’ journals</p> <p>Good sources to read: Source 1 Source 2 Source 3 Source 4 Video explaining the effects of antibiotic resistance Video explaining the process of antibiotic resistance</p>	<p><i>Journal check-in</i> Spend a few minutes answering reflection questions in journals. “What did you learn today? Who does antibiotic resistance impact? What questions do you still have about the process of antibiotic resistance?”</p> <p>Have them complete the solutions worksheet for homework</p>

	<p>question: “Can we still use colistin and other antibiotics to fight off bacterial infections?” Allow students to discuss in teams and then report their team consensus back to the entire class. An effective engagement question is an open-ended either/or question that stimulates further discussion and questions about the topic.</p>		<p>Further Questions: Why was colistin considered the last resort drug? How did the e.coli form a resistance to colistin if it wasn't really used? Can't we just make another antibiotic? How quickly does a resistance gene spread through bacteria populations?</p> <p>Lecture This is a time where you can lecture to your students about bacteria and how they become resistant to antibiotics. If your class is already knowledgeable about this topic, then you can skip this lesson. Ideas to include:</p> <ul style="list-style-type: none"> ● Antibiotics kill bacteria by targeting specific structures in bacterial cell walls and/ or metabolic processes that do not exist in human cells. This stops the bacterial cells from being able to function but does not affect human cells. ● Bacteria have genes in plasmids, which they can exchange. ● Antibiotic resistance genes can be exchanged between bacteria of the same and different species. ● Bacteria randomly mutate and can develop resistance to antibiotics, so these genes do not necessarily have to come from a bacteria that is already resistant. ● Bacteria are different than viruses structurally and biologically. Antibiotics only work on bacterial infections, not on viral infections. 		
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			<p><i>For homework:</i> research 5 bullets on possible solutions to antibiotic resistance.</p> <p>This would be a good time to have a discussion about sources. (This is a time to gauge whether your class has enough experience to judge the reliability of sources.)</p> <ul style="list-style-type: none">● What makes a good source?● Was the author biased? If so how could you confirm the information given by that source?● Is the source you're looking at a scientific source or one person's theory that probably isn't supported?		
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Solutions Worksheet

Name:

Directions: Research five solutions to antibiotic resistance. These can be ways to avoid developing and spreading resistance or possible alternatives to antibiotics. Cite your sources for each piece of information you find. Make sure to use **reputable** sources based on scientific facts.

Example: Overuse of antibiotics increases the chance of bacteria developing antibiotic resistance.

Source: http://emerald.tufts.edu/med/apua/about_issue/about_antibioticres.shtml

1.

2.

3.

4.

5.

Lesson 3-2: Topic Exploration

Time	Engaging the Student (entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~30 minutes	At the beginning of class, allow students 5 minutes in their teams to share information they researched for homework.	Topic Exploration Worksheet	<p>At the beginning of class, allow students time in their teams to share information they researched for homework.</p> <p>Have a class discussion about the effects and solutions on the board.</p> <p>Have each team choose one issue that interests them most about antibiotic resistance. Be sure to ask each team why they chose that topic.</p> <ul style="list-style-type: none"> Teams that say, "It's easy," are the teams that will lose interest the fastest. Be sure to articulate how important it is to choose a topic that each team member is interested in. <p><u>Homework:</u> Fill in Topic Exploration worksheet on their topic.</p>	Students' journals	<p><i>Journal check-in</i></p> <p>Spend a few minutes answering reflection questions in journals. "What issue did your team pick? Why? What do you know about this topic?"</p> <p>Have them complete the topic exploration worksheet for homework.</p>

Exploration Worksheet

Name:

Directions: Fill in the information below about your topic and answer the following questions. Be sure to include your sources for all of your answers.

Your Antibiotic Resistance solution: _____

Is your solution a method to reduce overuse of antibiotics or is it an alternative to antibiotics?

Explain how your solution works.

What are the benefits and drawbacks of your solution?

Pro	Con

Key terms, definitions, and significance (add extra on back):

Sources:

Lesson 4-1: Topic Diagram

~30 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>Diagram PB&J as an example of a system diagram around a topic (see video for an example of a demonstration diagram)</p> <p>This activity will require students to consider all facets of their topic, follow avenues of thought from beginning to end, examine cause and effect chains, and ask questions. One of their questions will lead to the team's research question.</p> <p>Each team makes their own system diagram. Students will draw a star next to the questions</p> <p>Stress that questions are just as important as what they know. (See video for an example of a student diagram)</p> <p>Have each team choose from their diagram a research question that they are most interested in answering. This selection leads into Lesson 4-2: Writing a research question.</p>	<p>Large sticky notes for each team</p> <p>Colored sharpies for each student</p>

Lesson 4-2: Writing a research question

Time	Engaging the Student (Entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~1 day	<p>List each team's research question on the board.</p> <p>Ask your class what makes a good research question? List their criteria on the board.</p>	<p>Variables Worksheet</p>	<p>Guide the discussion on research questions. Scientists generally agree that a good research question is:</p> <ol style="list-style-type: none"> 1. Testable using science 2. Specific 3. Answer should be objective rather than subjective 4. Able to be adapted into a hypothesis 5. Should address a gap in scientific knowledge 6. Not a question about a process because this should be addressed during the inception/engagement portions or can be done as background research. This would lead to reporting well-known information rather than drawing original conclusions. 7. Answering the question must be feasible within the time constraints <p>Give examples of bad and good research questions and characteristics of each</p> <p>Explain that the end goal of the research question is to guide research so that it will lead to original conclusions.</p> <p>Allow them to refine their research question using the variables worksheet.</p> <p>Have the students explain their research question and identify their independent and dependent variables to another team and have them respectfully critique each other's ideas.</p>	<p>Examples for teachers and students of the variables and study design worksheets.</p> <p>Guiding resource for students or teachers on research question process</p> <p>Source for teachers on the</p>	<p>Each team's exit ticket should be a research question that is approved by the instructor.</p> <p><i>Journal Check-in:</i> Spend a few minutes answering reflection questions in journals. "What was challenging about developing a research question? What made you choose your research question?"</p>

			Here is a video modeling how a conversation to narrow a research question might go.	difference between original research and reporting facts Students' journals	
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Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods will be required.

Research Question:

Independent Variable (The variable that you change and have control over):

What you know:

What you need to know:	How to find it: (if online, what type of source?)

Dependent Variable (The variable that reacts to the independent variable and that you will measure): _____

What you know:

What you need to know:	How to find it: (if online, what type of source?)

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question:

Which brand of dish soap, Dawn or Palmolive, would remove more motor oil from goose feathers?

Independent Variable: Type of dish soap

What you know:
Dish soap can get rid of dish grease Dawn has an initiative where they clean animals that have been covered in oil from oil spills

What you need to know:	How to find it: (if online, what type of source?)
What in soap gets rid of grease? What is different about each soap? Does soap dissolve in water?	Ingredients list for each soap/dish soap website Ingredients on soap containers Website explaining soap

Dependent Variable: Amount of grease removed from feathers

What you know:
Grease keeps birds from being able to fly It cannot wash off in the water, cannot be dissolved

What you need to know:	How to find it: (if online, what type of source?)
How much grease gets on birds when there is an oil spill? How long does the grease usually stay on for in seawater?	Oil spill info website Looking at what makes up each type of grease Animal rehabilitation websites

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Which brand of dish soap, Dawn or Palmolive, would remove the most motor oil from goose feathers?

Independent Variable: Type of dish soap

Dependent Variable: Amount of oil removed from feathers

Type of study: Experiment

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Measure and weigh a fixed amount of oil and weigh 10 feathers.
2. Douse a feather in the oil.
3. Use a fixed, weighed amount of one dish soap to clean the feather. Do this by scrubbing the feather from base to tip 5 times.
4. Immerse the feather in a beaker of water and allow to dry.
5. Repeat with 4 more feathers and 5 times with the other type of soap.
6. Once dried, reweigh each feather to evaluate the mass of oil lost through cleaning the feather.

Materials needed: (if applicable)

Goose feathers

Oil

Dawn and Palmolive soap

Beakers

Water

Analysis plan: Have some idea of how you will organize your data (this may change)

We will represent the mass of the oil removed in a bar graph and explained in words with pictures of the experiment.

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Where in my town would a community garden be most utilized by families?

Independent Variable: Location

What you know:
Must be in a green area Has access to sunlight and rain Somewhat central to the town

What you need to know:	How to find it: (if online, what type of source?)
Where can be accessed by public transportation?	City maps
Does it need to be accessible to those walking? Handicap accessible? Parking lot?	Find from study results, look up legality of community gardens
Legally, where would a garden be allowed?	Town hall website, city maps, employee at town hall

Dependent Variable: Number of potential users

What you know:
Families will use the garden

What you need to know:	How to find it: (if online, what type of source?)
Number of families in town? What number of families would like to use a community garden? How many families are able to use a car? Where do the most families live who would use the garden?	Town census Study results Study results Study results

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Where in my town would a community garden be most utilized by families?

Independent Variable: Location

Dependent Variable: Number of potential users

Type of study: Survey

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Write questions for survey from what is unknown about both of our variables
2. Distribute survey to families in our town
3. Collect data and tally answers to questions

Materials needed: (if applicable)

Printer and paper

Pens for survey participants to use

Location to hand out survey

Analysis plan: Have some idea of how you will organize your data (this may change)

1. Tally all answers and graph for each question (bar or pie graphs)
2. Overlay popular suggested locations and legally-possible locations on a map of the town
3. Make some final suggestions about where the community garden would be most utilized by families

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Is it more cost-effective to switch all our cities' streetlights to LED bulbs immediately or as the current non-LED light bulbs burn out?"

Independent Variable: When streetlight bulbs are switched

What you know:
Some cities are switching to LED street lights It costs money to change streetlights Options are to switch all at once or as lights burn out

What you need to know:	How to find it: (if online, what type of source?)
How many streetlights are in the city? When were they last installed? Were all of them installed at the same time?	City website/city employee

Dependent Variable: The cost of switching immediately or as lights burn out

What you know:
It will cost more in energy to have the non-LEDs in It will be a bigger upfront cost to put all LEDs in at once

What you need to know:	How to find it: (if online, what type of source?)
Labor prices in my town Non-LED cost? Energy used by non-LED bulbs? Cost of energy? LEDs cost? Energy used by LEDs?	Look online at average costs of other maintenance work (.gov) Ask town officials/power companies Online on lightbulbs' website Town's electricity grid website or employee
Which will cost less overall?	Study results

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Is it more cost-effective to switch all our cities' streetlights to LED bulbs immediately or as the current non-LED light bulbs burn out?"

Independent Variable: When streetlight bulbs are switched

Dependent Variable: The cost of switching immediately or as lights burn out

Type of study: Cost-benefit analysis

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Find data:
 - a. How much it costs for the LED lights and labor to put in per light
 - b. How much LED save vs lights used now per light
 - c. Other unknowns
2. Estimate how long each current light bulb has left before it needs to be replaced
3. Calculate the cost of replacing all at once or waiting till they burn out and compare to how much money would be saved

Materials needed: (if applicable)

None

Analysis plan: Have some idea of how you will organize your data (this may change)

A table that shows final cost of everything at the end of calculations

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Do paper or plastic bags generate more greenhouse gasses over their life cycle?

Independent Variable: Type of grocery bag

What you know:
<p>Paper bags are produced from trees and therefore contribute to deforestation Plastic bags are produced from oil Both can be recycled Some paper bags are thrown in landfills but some are littered Both are produced in factories Both need to be transported, raw material to factory, product to grocery store</p>

What you need to know:	How to find it: (if online, what type of source?)
<p>How many trees are cut down to make paper bags? How far away are the trees cut down for plastic bags? Can plastic bags be produced more locally than paper bags? How many paper and plastic bags are recycled, reused, thrown out, and littered? How are paper and plastic bags produced and recycled? How much can paper and plastic bags hold?</p>	<p>Bag manufacturing website/bag employee Production websites Test bags and production websites</p>

Dependent Variable: greenhouse gas generation

What you know:
<p>Occurs when fossil fuels are burned Occurs when waste breaks down Can also be exacerbated by deforestation which impacts greenhouse gas levels in the atmosphere: less sequestration, greater production (deforestation machinery and transportation) Occurs more the further something has to travel Can occur during recycling processes</p>

What you need to know:	How to find it: (if online, what type of source?)
<p>How much CO₂ does a tree take out of the atmosphere?</p> <p>How much CO₂ is produced from cutting down a tree?</p> <p>How many more plastic bags can be transported by the same amount of fuel?</p> <p>How much greenhouse gases is produced during recycling processes?</p> <p>How much CO₂ is produced during decomposition?</p> <p>How much CO₂ is produced in factories?</p> <p>How much greenhouse gas is produced in paper bag production?</p> <p>How much greenhouse gas is produced in plastic bag production?</p>	<p>Greenhouse gas website</p> <p>Bag manufacturing website/truck size data</p> <p>Recycling website</p> <p>Factory websites</p> <p>Study results</p> <p>Study results</p>

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question:

Do paper or plastic bags generate more greenhouse gasses over their life cycle?

Independent Variable: Type of grocery bag

Dependent Variable: Production of greenhouse gases

Type of study: Retrospective/online research

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Look up which bag produces more greenhouse gases during the following processes:
Extracting raw material, producing bag, transporting bag, recycling bag, throwing out the bag
2. Look up the percentage of time that paper and plastic bags are recycled and thrown out.
3. Look up the carrying capacity of each type of bag.

Materials needed: (if applicable)

Computer and internet

Analysis plan: Have some idea of how you will organize your data (this may change)

Part of the process	Paper	Plastic
Extraction of raw materials	How many trees are cut down to make one bag? How much CO ₂ is produced to cut down a tree?	How much CO ₂ is produced to get the materials to make a plastic bag?
Transportation	How far is the tree transported? How far is the bag transported? What is the efficiency of transporting paper bags? I.e. how many bags per truck? How much weight?	How far are the raw materials transported before they are turned into plastic bags? How far is the bag transported? What is the efficiency of transporting a plastic bag?
Production	How much greenhouse gases are produced when a paper bag is made from a tree into a bag?	How much greenhouse gases are produced when raw materials are made into plastic bags?

Use	How much weight can a paper bag hold?	How much weight can a plastic bag hold?
Recycling	How much CO ₂ is produced to recycle a paper bag? What percentage of paper bags are recycled?	How much CO ₂ is produced to recycle a plastic bag? What percentage of plastic bags are recycled?
Waste	What percentage of paper bags are thrown out in the garbage or are littered? How much greenhouse gases are produced during decomposition?	What percentage of plastic bags are thrown out in the garbage or are littered? How much greenhouse gases are produced during decomposition?

Once data is found in this chart, make a bar graph for greenhouse gas released by each type of bag.

Lesson 4-3: Forming a hypothesis

~20 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>A hypothesis is an educated guess that can take different forms. Sometimes it is in the form of, “If (something happens with your independent variable), then (something else will happen with your dependent variable).” Other times, it is an idea of what the outcome of a study will be, like, “Option A will have a certain outcome that is greater than/less than option B” or “Manipulating the independent variable will/will not have an impact on the dependent variable.” By the end of the research step, you should have found information that either surprises you or supports your hypothesis. Both of these are equally valuable, so don’t just try to find information that agrees with your hypothesis.</p> <p>You may want to provide your students with an activity to help them identify well-written and poorly-written hypotheses. This could be in a form of a worksheet, a discussion, or a board activity. Have students give justification for which proposed hypotheses are acceptable and which need improvement.</p> <p>Give teams time to form a hypothesis. Ask them to provide evidence from their background research to support their hypothesis.</p>	N/A

Lesson 4-4: Designing the study

~ 20 minutes

Student Version	Teacher Discussion Notes	Materials
Study design worksheet	<p>Explain how different types of research are done.</p> <ul style="list-style-type: none">• Some options: short-term experiment, study using others' data, survey to gauge awareness, cost-benefit analysis to compare two or more options, etc.• It is best to avoid a list of options from them to pick from. Rather it is best to give them some ideas and allow them to go in the direction that will best answer their question. <p>Have students design a study to answer their research question using the organizer worksheet.</p> <p><i>Journal Check-in:</i> Spend a few minutes answering reflection questions in journals. "How does your research design lead you to answering your research question?"</p>	<p>Examples for teachers and students of the variables and study design worksheets for a few different type of studies.</p> <p>Students' journals</p>

Study Design

Research Question:

Independent Variable: _____

Dependent Variable: _____

Hypothesis: _____

Type of study: _____

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

Materials needed: (if applicable)

Analysis plan: Have some idea of how you will organize your data (this may change)

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question:

Which brand of dish soap, Dawn or Palmolive, would remove more motor oil from goose feathers?

Independent Variable: Type of dish soap

What you know:
Dish soap can get rid of dish grease Dawn has an initiative where they clean animals that have been covered in oil from oil spills

What you need to know:	How to find it: (if online, what type of source?)
What in soap gets rid of grease? What is different about each soap? Does soap dissolve in water?	Ingredients list for each soap/dish soap website Ingredients on soap containers Website explaining soap

Dependent Variable: Amount of grease removed from feathers

What you know:
Grease keeps birds from being able to fly It cannot wash off in the water, cannot be dissolved

What you need to know:	How to find it: (if online, what type of source?)
How much grease gets on birds when there is an oil spill? How long does the grease usually stay on for in seawater?	Oil spill info website Looking at what makes up each type of grease Animal rehabilitation websites

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Which brand of dish soap, Dawn or Palmolive, would remove the most motor oil from goose feathers?

Independent Variable: Type of dish soap

Dependent Variable: Amount of oil removed from feathers

Type of study: Experiment

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Measure and weigh a fixed amount of oil and weigh 10 feathers.
2. Douse a feather in the oil.
3. Use a fixed, weighed amount of one dish soap to clean the feather. Do this by scrubbing the feather from base to tip 5 times.
4. Immerse the feather in a beaker of water and allow to dry.
5. Repeat with 4 more feathers and 5 times with the other type of soap.
6. Once dried, reweigh each feather to evaluate the mass of oil lost through cleaning the feather.

Materials needed: (if applicable)

Goose feathers

Oil

Dawn and Palmolive soap

Beakers

Water

Analysis plan: Have some idea of how you will organize your data (this may change)

We will represent the mass of the oil removed in a bar graph and explained in words with pictures of the experiment.

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Where in my town would a community garden be most utilized by families?

Independent Variable: Location

What you know:
Must be in a green area Has access to sunlight and rain Somewhat central to the town

What you need to know:	How to find it: (if online, what type of source?)
Where can be accessed by public transportation?	City maps
Does it need to be accessible to those walking? Handicap accessible? Parking lot?	Find from study results, look up legality of community gardens
Legally, where would a garden be allowed?	Town hall website, city maps, employee at town hall

Dependent Variable: Number of potential users

What you know:
Families will use the garden

What you need to know:	How to find it: (if online, what type of source?)
Number of families in town? What number of families would like to use a community garden? How many families are able to use a car? Where do the most families live who would use the garden?	Town census Study results Study results Study results

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Where in my town would a community garden be most utilized by families?

Independent Variable: Location

Dependent Variable: Number of potential users

Type of study: Survey

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Write questions for survey from what is unknown about both of our variables
2. Distribute survey to families in our town
3. Collect data and tally answers to questions

Materials needed: (if applicable)

Printer and paper

Pens for survey participants to use

Location to hand out survey

Analysis plan: Have some idea of how you will organize your data (this may change)

1. Tally all answers and graph for each question (bar or pie graphs)
2. Overlay popular suggested locations and legally-possible locations on a map of the town
3. Make some final suggestions about where the community garden would be most utilized by families

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Is it more cost-effective to switch all our cities' streetlights to LED bulbs immediately or as the current non-LED light bulbs burn out?"

Independent Variable: When streetlight bulbs are switched

What you know:
Some cities are switching to LED street lights It costs money to change streetlights Options are to switch all at once or as lights burn out

What you need to know:	How to find it: (if online, what type of source?)
How many streetlights are in the city? When were they last installed? Were all of them installed at the same time?	City website/city employee

Dependent Variable: The cost of switching immediately or as lights burn out

What you know:
It will cost more in energy to have the non-LEDs in It will be a bigger upfront cost to put all LEDs in at once

What you need to know:	How to find it: (if online, what type of source?)
Labor prices in my town Non-LED cost? Energy used by non-LED bulbs? Cost of energy? LEDs cost? Energy used by LEDs?	Look online at average costs of other maintenance work (.gov) Ask town officials/power companies Online on lightbulbs' website Town's electricity grid website or employee
Which will cost less overall?	Study results

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question: Is it more cost-effective to switch all our cities' streetlights to LED bulbs immediately or as the current non-LED light bulbs burn out?"

Independent Variable: When streetlight bulbs are switched

Dependent Variable: The cost of switching immediately or as lights burn out

Type of study: Cost-benefit analysis

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Find data:
 - a. How much it costs for the LED lights and labor to put in per light
 - b. How much LED save vs lights used now per light
 - c. Other unknowns
2. Estimate how long each current light bulb has left before it needs to be replaced
3. Calculate the cost of replacing all at once or waiting till they burn out and compare to how much money would be saved

Materials needed: (if applicable)

None

Analysis plan: Have some idea of how you will organize your data (this may change)

A table that shows final cost of everything at the end of calculations

Variables Worksheet

At this point in your research process, you have chosen a research question that will be the focus of the rest of this case study. In order to understand what you still need to look into to answer your research question, fill out this chart with what you know and what you need to know about each variable. The purpose of this worksheet is to understand the next steps in your research and what research methods you may need to use in order to do this.

Research Question: Do paper or plastic bags generate more greenhouse gasses over their life cycle?

Independent Variable: Type of grocery bag

What you know:
<p>Paper bags are produced from trees and therefore contribute to deforestation Plastic bags are produced from oil Both can be recycled Some paper bags are thrown in landfills but some are littered Both are produced in factories Both need to be transported, raw material to factory, product to grocery store</p>

What you need to know:	How to find it: (if online, what type of source?)
<p>How many trees are cut down to make paper bags? How far away are the trees cut down for plastic bags? Can plastic bags be produced more locally than paper bags? How many paper and plastic bags are recycled, reused, thrown out, and littered? How are paper and plastic bags produced and recycled? How much can paper and plastic bags hold?</p>	<p>Bag manufacturing website/bag employee Production websites Test bags and production websites</p>

Dependent Variable: greenhouse gas generation

What you know:
<p>Occurs when fossil fuels are burned Occurs when waste breaks down Can also be exacerbated by deforestation which impacts greenhouse gas levels in the atmosphere: less sequestration, greater production (deforestation machinery and transportation) Occurs more the further something has to travel Can occur during recycling processes</p>

What you need to know:	How to find it: (if online, what type of source?)
<p>How much CO₂ does a tree take out of the atmosphere?</p> <p>How much CO₂ is produced from cutting down a tree?</p> <p>How many more plastic bags can be transported by the same amount of fuel?</p> <p>How much greenhouse gases is produced during recycling processes?</p> <p>How much CO₂ is produced during decomposition?</p> <p>How much CO₂ is produced in factories?</p> <p>How much greenhouse gas is produced in paper bag production?</p> <p>How much greenhouse gas is produced in plastic bag production?</p>	<p>Greenhouse gas website</p> <p>Bag manufacturing website/truck size data</p> <p>Recycling website</p> <p>Factory websites</p> <p>Study results</p> <p>Study results</p>

Study Design

This worksheet is meant to give students an organizer to develop their study and make sure they have thought through what they need to know in order to successfully do a study.

Research Question:

Do paper or plastic bags generate more greenhouse gasses over their life cycle?

Independent Variable: Type of grocery bag

Dependent Variable: Production of greenhouse gases

Type of study: Retrospective/online research

Procedure: Write the steps for your data collection (this may be a great place to delegate tasks)

1. Look up which bag produces more greenhouse gases during the following processes:
Extracting raw material, producing bag, transporting bag, recycling bag, throwing out the bag
2. Look up the percentage of time that paper and plastic bags are recycled and thrown out.
3. Look up the carrying capacity of each type of bag.

Materials needed: (if applicable)

Computer and internet

Analysis plan: Have some idea of how you will organize your data (this may change)

Part of the process	Paper	Plastic
Extraction of raw materials	How many trees are cut down to make one bag? How much CO ₂ is produced to cut down a tree?	How much CO ₂ is produced to get the materials to make a plastic bag?
Transportation	How far is the tree transported? How far is the bag transported? What is the efficiency of transporting paper bags? I.e. how many bags per truck? How much weight?	How far are the raw materials transported before they are turned into plastic bags? How far is the bag transported? What is the efficiency of transporting a plastic bag?
Production	How much greenhouse gases are produced when a paper bag is made from a tree into a bag?	How much greenhouse gases are produced when raw materials are made into plastic bags?

Use	How much weight can a paper bag hold?	How much weight can a plastic bag hold?
Recycling	How much CO ₂ is produced to recycle a paper bag? What percentage of paper bags are recycled?	How much CO ₂ is produced to recycle a plastic bag? What percentage of plastic bags are recycled?
Waste	What percentage of paper bags are thrown out in the garbage or are littered? How much greenhouse gases are produced during decomposition?	What percentage of plastic bags are thrown out in the garbage or are littered? How much greenhouse gases are produced during decomposition?

Once data is found in this chart, make a bar graph for greenhouse gas released by each type of bag.

Lesson 4-5: Conducting the research

Time	Engaging the Student (Entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~2-3 days	At the beginning of each research day ask teams to set goals for the day.	Information organizer	<p>Allow teams time to complete their study. Offer help and check in as needed.</p> <p>Have students analyze data. Some studies will have more obvious methods of analysis than others and guidance can be given to teams individually. Some options include: graphs spreadsheets with totals and percentages, cost benefit analyses, statistical analysis, etc.</p>	various	<p>At the end of each research day, you can ask students to complete the following.</p> <p><i>Journal Check-in:</i> Spend a few minutes answering reflection questions in journals. “When were you most productive today? What do you still need to do to answer your research question?”</p> <p>Alternatively you can ask students to work across teams: Ask students to pair up with another team and explain what they have done so far and what they still hope to do. Have them ask questions about their process during the research phase.</p>

Lesson 5-1: Drawing a conclusion

~20 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	Have students draw conclusions from data analysis. <ul style="list-style-type: none"><li data-bbox="435 436 1084 506">• Teams should take a position on their research question.<li data-bbox="435 516 1149 625">• Each team should write out a few sentences stating its claim and the major pieces of evidence the claim is based upon.	N/A

Lesson 5-2: Communicating your findings

Time	Engaging the Student (Entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~60 minutes	<p>Tell the students that they will be creating a product that will be going outside of the classroom and communicates their findings.</p> <p>Hand out the product expectations and review them with the class.</p>	<p>Expectations for Product Handout</p>	<p>Teams should discuss what audience and medium are most suitable for their research and conclusions first. You may ask them to get their proposed medium and audience approved by you before continuing.</p> <p>Create step examples are provided</p> <p>Time should be allotted to writing a first draft of their product.</p>	<p>Create Step Examples</p>	<p><i>Journal Check-in:</i> Spend a few minutes answering reflection questions in journals. “How did you choose your audience? Why are they the best audience to reach with your conclusion and research in order to address the societal problem?”</p>

Expectations for Product Handout

You will make a product that communicates your findings to an audience outside the classroom. This can be a proposal for a policy change, governmental action, or education program at the school or community level; a public service announcement on the radio or in a newspaper; a letter to the editor, mayor or principal, etc. You may decide which method of communication is most effective for the type of information your team has found and which medium would reach the audience you feel would most benefit from learning about your scientific conclusion.

The product should:

- Introduce your problem/topic (Antibiotic Resistance)
- Share your findings and conclusions from your research
- Have a message: a call to action, why the findings and conclusions matter, what impact the conclusions have on the societal problem
- Language should be suitable for the audience (a letter to a mayor should be formal, a public service announcement should avoid jargon)

Create step examples: (These are examples, but not necessarily exemplars!)

Dear members of the United Nations,

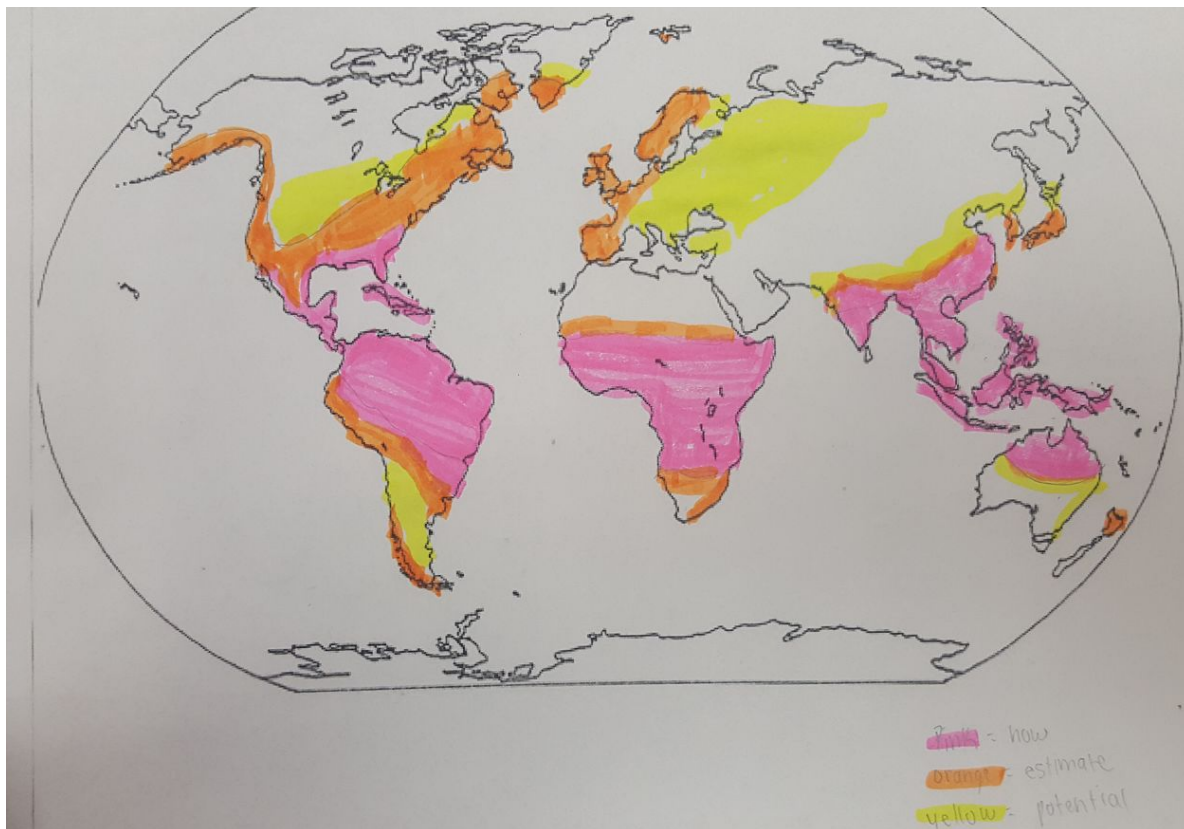
We are students of Chicopee High School in Massachusetts, US. For the last two weeks we have been researching how the absence of elephants in a greenland environment can affect the environment itself. From our research, elephants are key to their environment because they contribute to the well-being of the natural environment as well as the other animals in this habitat. There are currently 470,000 elephants existing in the Sahara and Central Africa. The reason for such a low population is over-hunting and humans expanding into their habitats.

But why should we care what happens to elephants? Elephants are one of, if not the most important animals in their environments. They truly shape their habitat from clearing dead trees to making room for new ones to making water holes for other animals and themselves to drink. For example elephants make trails through tall grass. This helps other animals get away from brush fires. They also spread seeds without knowing. In fact there are some seeds in the African greenlands that need to be grown by going through the elephant's digestive system. Elephants play key roles in their habitats and without them many organisms would not be able to survive.

So what happens when the elephants in an area are gone? First off there will be a decrease in the water supply due to the lack of water holes that elephants usually create. Also, there will be an increase in dead trees. Because of the dead trees, new trees won't be able to grow causing a decrease in healthy air. Brush fires are common in these environments and would claim the lives of hundred of animals with no elephant trails for escape. Without elephants, some seeds wouldn't grow causing an entire type of plant to go extinct. This could cause the beautiful green land to turn to a barren wasteland.

As you can see, elephants are key to their habitats and the animals there. This is why we should all do whatever we can to save the elephants and to stop poachers from killing these important animals. We recommend an increase in the guard on the elephants to help them survive and a fine on the poachers that is greater than the amount they would make from the ivory. Thank you for hearing our ideas and concerns on this topic. We truly hope you help the elephants and keep up the good work.

Map of predicted Zika spread based on climate change data and mosquito climates:



pink=current areas where the mosquitos that can carry Zika live

orange=estimated spread of these mosquitos with climate change

yellow= if Zika were to spread to the orange areas, Zika could spread by human transmission to these places

Dear Mayor Kos,

In a recent study at Chicopee Comprehensive High School, my classmates and I have done research about the economic and environmental benefits of electric cars. Currently in our area we only have two electric car plug stations; those locations are 500 Memorial drive and 765 Memorial drive. We have found that electric cars are beneficial for the environment and can cost less on average. Although they do burn CO₂ while charging, electric cars don't burn any fossil fuels or have any tailpipe emissions. They have a lower cost per mile and cost less for maintenance. Currently there is 53.3 years worth of oil left on Earth. When the oil runs out we will need a new method of transportation. If we are going to transition to electric vehicles, we need more charging spaces in Chicopee. Therefore we are asking to have more plug-in stations in the city, so this eco-friendly option is available to everyone.

Lesson 5-3: Peer-editing

Time	Engaging the Student (Entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~45 minutes	Pair up the teams. Have them exchange their products for peer-editing.	N/A	<p>Students should revise based on their peers' critiques and then submit their product to the teacher for a final edit and approval before sending to their audience.</p> <p>Teams may need an entire day and night to revise before handing them into the instructor.</p> <p>Products can be revised a final time by the instructor and returned for a final round of edits before sending them out to the audiences.</p>	N/A	<p><u>Journal Check-in:</u> Spend a few minutes answering reflection questions in journals. "What feedback did you receive on your product? What was helpful about it?"</p>

Lesson 5-4: Presenting

Time	Engaging the Student (Entry Task)	Developing the Ideas--Lesson			Checking for Understanding (exit ticket)
		Student Handout	Teacher/Lecture Notes	Materials	
~2 days	<p>Introduce presentations and handout presentation expectations.</p> <p>We recommend you specify presentation length and set a firm maximum length.</p>	<p>Expectations for presentation handout</p>	<p>Students should begin preparing presentations their presentations.</p> <p>Present. Encourage students to ask questions during their peers' presentations.</p>	<p>Some students may need an overhead projector and access to a computer.</p>	<p>Ask students the following questions:</p> <p>What did you learn from other teams' presentations?</p>

Expectations for Presentation Handout

Your team will give a presentation to tell the class what you have learned and accomplished during this case study. Remember that this presentation is not your main product, but rather a tool for communicating your findings and your process.

Your presentation should include:

- Introduction to the team's topic and how it is related to the broader case study topic of Antibiotic Resistance
- Research question,
- Research methods and study design,
- Findings and conclusions,
- Product, audience, and why you chose these,
- Possible improvements to study design and further questions.
- Visual component

Lesson 6-1: Reflection

~40 minutes

Student Version	Teacher Discussion Notes	Materials
N/A	<p>Come up with questions that ask students to draw from their experiences and from feedback they received. Here are some sample questions:</p> <p>What got you excited?</p> <p>How did you learn best? (hands-on, reading, online, asking questions, etc.?)</p> <p>What did you learn? (Content)</p> <p>How have you improved in the following areas:</p> <ol style="list-style-type: none">1. Asking scientific questions2. Gathering reliable scientific information3. Drawing conclusions from data4. Communicating scientifically5. Giving and receiving feedback <p>What mistakes did you make? How have you learned from those mistakes? If you had to do it over again, what would you change about the process?</p> <p>How close did you get to actually solving the problem? How much progress did you make? What would be the next steps you would need to do to move a solution forward?</p> <p>How well did your team work together?</p> <p>Ask students to reflect in journals for 10 minutes, then share some of their ideas with their teams for 5 minutes.</p> <p>We recommend that you seat students in a circle and join them there.</p> <p>Ask students to share their responses to the questions. If students are reluctant to share, you could ask “How did someone in your team respond to this question?” Encourage students to respond to each other. Ask students for feedback on how this case study curriculum could be improved.</p>	Journals