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
Timeline: ~1 day Discipline: Any	BIG IDEA 1: How the case study may be different than what students are used to, and what the expectations are. Essential Questions: 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?	In these three lessons students are introduced to the case study approach. 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.	Lesson 1-1: Introduction to learning styles Lesson 1-2: Expectations for the case study Lesson 1-3: Working in teams		Ask the Questions: 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?
Timeline: ~1 day Discipline: Science, Environmental Studies	**Inception** BIG IDEA 2: Ocean acidification has significant impacts on marine life, particularly oysters Essential Questions: 1. What is the impact of	In these lessons, students are introduced to the topic of the case study and become invested in it. Students are polled on ocean	Lesson 2-1: Polling the students Lesson 2-2: Inception video		Ask the question: 1. Who does ocean acidification affect?

	ocean acidification on oysters?	acidification and watch an inception video on oyster farmers.			
Timeline: ~2 days Discipline: Environmental Studies, Science	**Engagement** BIG IDEA 3: Defining ocean acidification Essential Questions: 1. What is ocean acidification? 2. How is is the movement of the oyster farmers related to ocean acidification? 3. What are the causes, effects and solutions of ocean acidification?	Through these lessons students become engaged in the topic of ocean acidification. Students will discuss whether moving the oyster farm is a permanent solution, and will create a class list of causes, effects and solutions. Each team will pick an issue.		Lesson 3-1: Engagement Question and Ocean Acidification Lecture Lesson 3-2: Discussion of Effects and Solutions of Ocean Acidification	Ask the question: 1. What is the process of ocean acidification?
Timeline: ~1 week Discipline: Science	**Research** BIG IDEA 4: Scientific inquiry skills can be used to address ocean acidification Essential Questions: 1. What is known about this topic? What is not known? 2. How do you write a	In these lessons, students collect background information on their topic, write a research question, and collect data and information to answer their research question.	Lesson 4-1: Topic diagram Lesson 4-3: Form a hypothesis Lesson 4-4: Designing the study	Lesson 4-2: Writing a research question Lesson 4-5: Conducting the research	Discuss with each team whether they have gathered enough information to answer their research question. Do they have the evidence to support their position? Are they missing a piece of

	research question? 3. How should I collect my information? 4. Which sources are reliable and reputable?				information?
Time: ~1-2 days Discipline: Science,	**Create** BIG IDEA 5: Scientific communication can be used to address ocean acidification Essential Questions: 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 ocean acidification?	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	Lesson 5-2: Communicating your findings Lesson 5-3: Peer-editing Lesson 5-4: Presenting	Ask the following questions: Compare and contrast yours and your classmates communication pieces. What do you think these communication pieces will accomplish?
Time: ~1 day Discipline: Any	**Reflect** BIG IDEA 6: Reflection is a tool for improving your scientific inquiry skills and for identifying the next steps for addressing ocean acidification	In this lesson students will reflect on their process recognize their strengths, their opportunities for growth, and what they have learned	Lesson 6-1: Reflect		N/A

	<u>Essential Questions</u>: 1. What have I learned? 2. What have I done well? 3. How can I improve?	and accomplished.			

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 Ocean Acidification. Ocean acidification refers to the lowering pH of the ocean due to increased levels of carbon dioxide diffused into the ocean from the atmosphere. Students are introduced to this topic through a video about oyster farmers impacted by the acidity of the ocean. Later, student teams choose an impact, a solution or mitigation strategy to research further. By the end of the case study each team will have moved the needle forward on understanding and solving ocean acidification.

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.HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

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-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
*HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
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-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
*HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

*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 ocean acidification 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.