1. General Lesson Information

Briefly describe the lesson, including major content covered, required knowledge (by the person teaching it), and general activities (this is an overview for volunteers and for classroom teachers):

Lesson Title	**The effect of Ocean Acidification on shells**
Topics Covered	**Climate change, ocean acidification**
NGSS connections (link to NGSS website)	**(Example: HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales)**
What will students know at the end of this lesson?	**The Earth's climate is determined by the balance of incoming and outgoing heat. This balance has been disturbed by the additional carbon dioxide added to the Earth's atmosphere over the last 200 years. As a result, atmospheric and ocean temperatures are increasing, faster than at any previously recorded point, and the ocean's are acidifying. This acidification of the ocean may be harmful to calcifying organisms.**
What will students be able to do at the end of this lesson?	**Make predictions about future ocean conditions with climate change** **Develop and test a hypothesis about how changes to pH will affect calcium carbonate shells**
How long will this lesson take?	**2 class periods (45-60 minutes each)**
Required prior knowledge	**pH scale**
Targeted grade level	**9-10**

How does this lesson fit into a larger sequence of content? Is this a standalone activity or part of a sequence?	**Originally, this lesson was designed as part of a larger unit on shellfish and aquaculture, intended to show how climate change could potentially impact the shellfish that constitute a huge industry in Washington state. The lesson could easily be tweaked to focus on other organisms (such as corals) or regions of the ocean, as well as be adjusted to have a different start and end point.**
What is the ideal site for this lesson/activity (classroom, lab, boat, beach, etc)	**Day 1: classroom** **Day 2: lab**
What science skills will students use in this activity?	**Develop and test a hypothesis** **Make measurements using scientific equipment** **Analyze data and figures**
What type of project could this be linked to?	**Aquaculture** **Climate change impacts**
What special skills do students need (i.e. coding, pipetting, etc)	**None**
What interdisciplinary connections could there be with this lesson?	**Social impacts of climate change**
How could this lesson be adapted for younger or older students?	**Younger: Focus more on the experimental portion of the lab** **Older: Add in more equilibrium chemistry**

2. Lesson Details

I. CHECKING PRIOR KNOWLEDGE Identify how you will inventory student knowledge ahead of the task, lesson, or activity. (e.g., communication with teacher, previous day's exit tickets shared by teacher, warm-up activity, class discussion, etc.)	**The lesson begins by asking students what they know, have heard, and want to know about climate change. An important part of the lesson design is to discuss these questions (not the answers, just that the questions exist) and then return to them throughout the lesson as appropriate.**

II. STUDENT QUESTIONS ADDRESSED How will you identify what questions students have, and incorporate these questions into your lesson?	**See box above**
III. KEY VOCABULARY Note which terms or academic vocabulary will be essential to this lesson. If you serve English language learners, consider what additional vocabulary might be necessary for them to access the content/skills during the instructional activities.	**Climate change** **pH** **Acidification** **Weather and climate**
IV. FORMATIVE ASSESSMENT How will you gather info on what students are learning during and at the end of the lesson? How will you make sure this information is shared between the lesson presenters and the classroom teacher?	**The lesson is designed to give students opportunities to talk to each other as well as the whole class. These are really good opportunities to hear what students are thinking and build in additional responses as necessary (or make adjustments for the Day 2 lesson)**
V. LESSON PLAN A recommended framework for designing your lesson is displayed to the right, known as the 5E framework. This is a way to encourage lesson planners to center lessons on students questions and student exploration, rather than having lessons be teacher centered. In this section, you can also include: ● Possible enrichment activities for students who are interested in pursuing the content further	**ENGAGEMENT** · **Describe how the teacher will capture students' interest.** · **What kind of questions should the students ask themselves after the engagement? (please note that as much as possible the goal is to build on student questions rather than purely teacher questions)** **Day 1 Intro:** What do you know about climate change? What have you heard about climate change but aren't sure is true? What questions do you have about climate change? –Students put answers on post-its and put it on big chart paper? Padlet –Students share out some responses at their paper It is important to keep track of these questions and make sure to return to them later, when appropriate.
	EXPLORATION · **Describe what hands-on/minds-on activities students will be doing.** · **List "big idea" conceptual questions the teacher will use to encourage and/or focus students' exploration** Intro (5 minutes): Climate vs. weather activity (closet analogy) (How can we use this to respond to people who say things like, "Climate change can't be real because it snowed!") Activity (20 minutes for groupwork, 10 minutes for share-out): Students pick a question they are interested in exploring and work with groups to come up with an answer to present to the class (other students record notes). Question for each group of figures:

	1. What determines the Earth's climate? 2. How do we know the climate is changing? 3. Why is the climate changing? 4. How does climate change affect the ocean? Sample figures for students to use to explore each of these questions is included in the folder. Feel free to find your own as well, but three figures per group works pretty well. Students should have about 20 minutes to explore their figures, and then share out what they learned (more detail in slides below)
	EXPLANATION · **Student explanations should precede introduction of terms or explanations by the teacher. What questions or techniques will the teacher use to help students connect their exploration to the concept under examination?** · **List higher order thinking questions which teachers will use to solicit *student* explanations and help them to justify their explanations.** **Use some of the figures from the group exploration to summarize why the climate is changing AND how we know.**
	ELABORATION · **Describe how students will develop a more sophisticated understanding of the concept.** · **What vocabulary will be introduced and how will it connect to students' observations?** · **How is this knowledge applied in our daily lives?** **What is climate change doing to the ocean?** 1. Dry ice activity (works with a soda stream as well!): show how pH changes when carbon dioxide is introduced (can use cabbage juice as a pH indicator, but need to show/explain what different colors mean first) a. Where is the carbon dioxide coming from in real life? How are the processes in the ocean/atmosphere similar to the soda stream? b. https://www.youtube.com/watch?v=MgdlAt4CR-4 AND https://www.youtube.com/watch?v=kxPwbhFeZSw c. Watch videos with students and have them make observations/share what they heard. Can also pause and rewatch the videos (they're short!) d. Before doing the shell dissolution activity, have students use evidence (from video or slides) to explain what ocean acidification is and how it affects shell-growing

	organisms 2. Experiment/demo (can tweak this depending on time/materials) a. Option 1: short term observation using egg shells and a variety of liquids. Can either submerge bits of egg shell or drop bits of liquid on them using an eyedropper/pipette b. Option 2: long term observation/measurement of shells in a variety of liquids. This can be purely observational or involve gathering data with sensors. If equipped, you could help them set up a time-lapse video, connect sensors (like the Vernier classroom sensors, which some teachers have), or some other mechanism for gathering data. c. Students can also take before/after measurements of shell dimensions, mass, etc. d. What similarities are there between the objects (seashells, eggshells, pteropods (we won't have these but they're in a video))? e. What is the pH of each of the liquids? f. How will we know what the change is? (can think about the liquid AND the shells) g. How long do we want to observe for? h. Submit: hypothesis for this experiment (support it with the videos they just watched)
	EVALUATION · **How will students demonstrate that they have achieved the lesson objective?** · **This should be embedded throughout the lesson as well as at the end of the lesson**
VI. SCAFFOLDS Scaffolds are intended to be temporary supports that are removed when students no longer need them. For written activities, this may include providing recommended vocabulary to incorporate, sentence starters, or a response framework (such as "Claim-Evidence-Reasoning". For analyzing data, this may include prompts for how to start looking at the data and/or a set of increasingly complex questions for students to respond to (starting with very straightforward observations).	**1. During the climate change activity, some of the figures are quite complex. It is helpful to have some guiding questions that students can use to orient themselves to the figures before they start trying to figure out what they mean (when appropriate, this might be something like, "What is on the x-axis? What is on the y-axis? Is the graph scale evenly? How do you know? What do the colors mean? Is the graph showing an increase or a decrease?)** **2. If you can, it makes sense to reach out to a partner teacher ahead of time to get help assigning groups. Make sure the teacher has had a chance to look at the figures provided for each climate change question, so they can think about how to appropriately divide students up.** **3. There are quite a few options for what the "experiment" looks like, and it will depend on what resources are available and students' prior experience setting up experiments. It is helpful to talk to the teacher ahead of time about how much structure students will need. You can share the handout, which has some structure, and then make adjustments according to feedback from the teacher.**

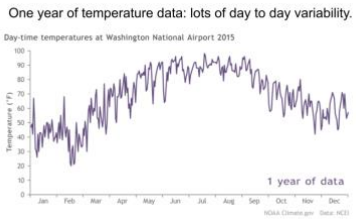
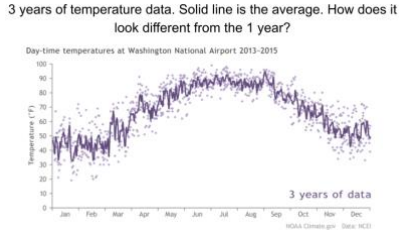
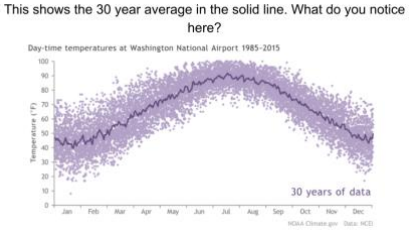
VII. REFLECTION How will presenters gather information about the success of the lesson, reflect, and incorporate this into future versions of the lesson?	**Exit tickets each day (can be anonymized) provide a general idea of what students are taking away from the lesson. Ideally, exit tickets could be on post-it notes or notecards rather than on student handouts.**
IX. TOOLS/RESOURCES Student-facing tools (such as handouts, "Notecatchers", or worksheets), human resources such as experts or community members, teacher tools, equipment (please be as specific as possible to make sure that all resources required for the lesson are available), etc. If special materials are required, please be clear about who is responsible for providing them and/or how schools can acquire them.	**Printed handouts (figures for the** **Parts of the lesson include showing very short videos, so it's important to know if the classroom is equipped for that.** **Lab equipment for day 2:** **Dry ice OR Soda stream** **Cabbage juice indicator** **Shells (eggshells, seashells)** **Vinegar** **Carbonated water** **Regular water** **Eye droppers/pipettes** **Jars** **Mass balance/scale** **pH indicator/test strips** **Other experimental equipment as discussed with the teacher**

3. Detailed lesson outline

Day 1	**Intro to Climate Change** This is currently designed as a two day intro to Climate Change and Ocean Acidification, but could easily be modified to different formats.

Day 1: Intro to Climate Change	
Slide 2	
What do you know about climate change Student responses:	Warm-up with students. Students should have the opportunity to record their answers privately (in writing, through an online poll, or some other way) before answers are shared out. If students are writing their answers down, they can share out (resist the urge to try to answer things or correct any statements they make). If answers are recorded electronically, you can read out some of them.
Slide 3 What have you heard about climate change but aren't sure about Student responses:	Warm-up with students. Students should have the opportunity to record their answers privately (in writing, through an online poll, or some other way) before answers are shared out. If students are writing their answers down, they can share out (resist the urge to try to answer things or correct any statements they make). If answers are recorded electronically, you can read out some of them.

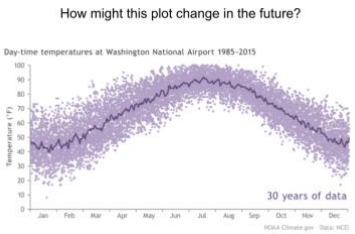
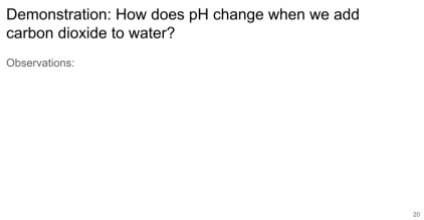
Slide 4 What questions do you have about climate change? Student responses:	Warm-up with students. Students should have the opportunity to record their answers privately (in writing, through an online poll, or some other way) before answers are shared out. If students are writing their answers down, they can share out (resist the urge to try to answer things or correct any statements they make). If answers are recorded electronically, you can read out some of them. This is an important part of the warm-up/hook/introduction, because the goal of the lesson is to revisit some of these questions as the lesson progresses.
Slide 5 What is the difference between weather and climate? Student responses:	Sample script: “Now that we’ve talked about what we think we know and what questions we have, let’s start exploring what’s going on with climate change. An important part of this is understanding the difference between weather and climate. I’d like to hear some ideas about what the difference might be.
Slide 6 What is the difference between weather and climate?  	Here is an analogy. Relate this comparison to student comments.

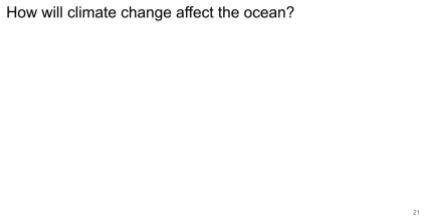
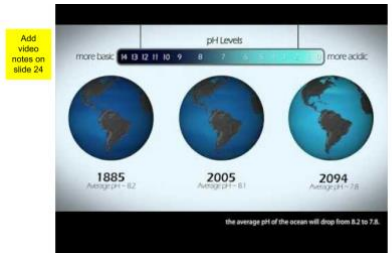
Slide 7 	Here is another way to think about the difference between weather and climate. Here is a graph showing the temperature each day for an airport in Washington DC (could also pick a different, more relevant location). Orient students to the axes. What do you notice about the temperature day to day? Pick a date on the map right before a large spike. If you knew the temperature on this day, how accurately do you think you could predict the temperature for the next day? The next week?
Slide 8 	Now we've averaged three years of data together (dark purple line). The background dots show individual measurements. What do you notice about the purple dots? How does the 3-year average compare to the temperatures shown by the individual dots?
Slide 9 	Now we've averaged 30 years of data together. This is what we mean when we talk about the climate: the average picture of the temperatures experienced throughout the year. What do you notice about the dark purple line now?

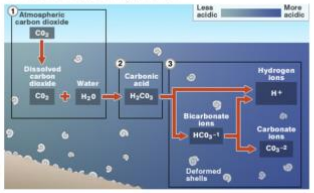
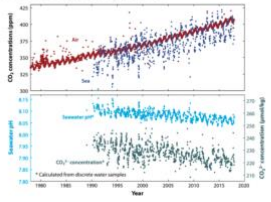
Slide 10 Some questions about climate change: 1. What determines the Earth's climate? 2. How do we know the climate is changing? 3. Why is the climate changing? 4. How does climate change affect the ocean?	Based on some of the questions students shared earlier, we're going to start thinking about how we know what we know about climate change using these four questions as a starting point. Depending on how many students are in the class and the size of groups, each question will probably have 1-3 groups working on it.
Slide 11 Today's Activity: 1. In your group, you will investigate one of the four questions identified on the previous slide. a. Step 1: Write down what you think you know about the answer to this question. b. Step 2: Look at the 3 figures provided to your group. For each figure, write down your observations about the figure: What is it? What is graphed, plotted, or illustrated? What is it showing you? c. Step 3: Use your observations from the figure to help you answer your group's question more fully. d. Step 4: Record your answer on your notecatcher. You should use one or more of the figures as supporting evidence and write out a short explanation. You will present this to the class.	Each group will receive a set of 3 images. Some of them are schematics, some of them are graphs. Figures are organized by question in the folder. Feel free to find and add your own figures if you prefer. Provide directions for the activity. Students should get 20 minutes to work on this will you circulate, ask questions, provide support, etc.
Slide 12 Group Share-out As your classmates share out, record your notes in your notecatcher. Prepare any questions you have to ask other groups when they are done presenting. 1. What determines the Earth's climate? 2. How do we know the climate is changing? 3. Why is the climate changing? 4. How does climate change affect the ocean?	Starting with question 1, have groups share out their responses. If there is more than one group per question, after the first share-out, you can ask the other groups what they would like to add to the initial response, how they answered the question differently, etc.

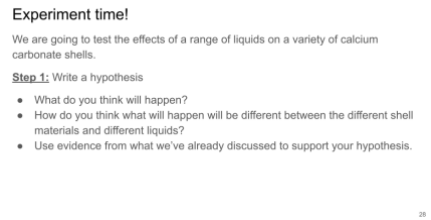
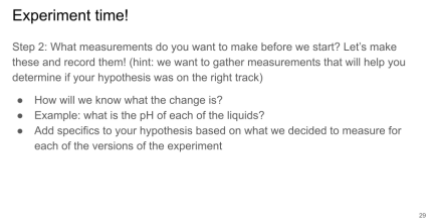
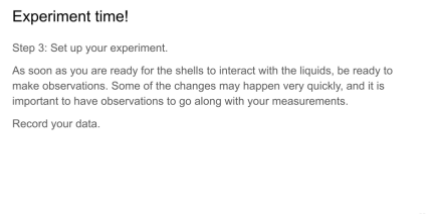
Slide 13 Why is the climate changing?	Whole class summary discussion. This would be a great time to work with the teacher to facilitate.
Slide 14 Silent Poll: What year did “we” “discover” climate change? •“A great deal has been written on the influence of the absorption of the atmosphere upon the climate...” •“We now possess all the necessary data for an estimation of the effect on Earth’s temperature which would be the result of a given variation of atmospheric carbon dioxide [CO2].” •A doubling of atmospheric CO2 would cause an increase in global temperature of about 5ºC”	If any students asked “How long have we known/when did we know?” or something similar, you can reference that. Otherwise, it can just be an interesting question to ponder. It’s important for students to think about this on their own so that they can come up with an answer that feels true to them. One way to facilitate sharing out is to have everyone stand up, and then count backward by decades (starting with 2010, for example), and have students sit down when you’ve reached the year they think we knew about it. I.e. “Sit down if you think we figured this out after 1990. . . 1980. . .” In previous classes, most student responses have been after 1960.
Slide 15 Silent Poll: What year did “we” “discover” climate change? •“A great deal has been written on the influence of the absorption of the atmosphere upon the climate...” •“We now possess all the necessary data for an estimation of the effect on Earth’s temperature which would be the result of a given variation of atmospheric carbon dioxide [CO2].” •A doubling of atmospheric CO2 would cause an increase in global temperature of about 5ºC” 	Share the answer. How does this make you feel?

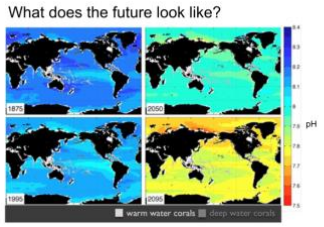
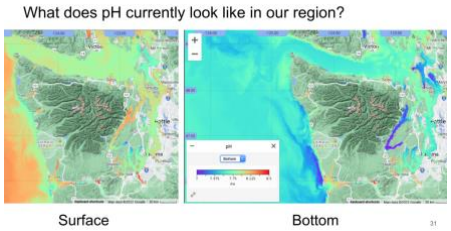
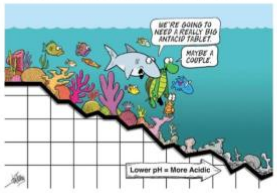
Slide 16 Exit Ticket What questions did you have about climate change that you can now answer? What do you think the future looks like?	Provide small slips of paper for students to respond on so that you and the teacher can collect the answers and look through them. Some teachers may prefer to do this electronically, which is also fine. Ideally, you could see student responses in case there is anything you want to revisit on Day 2 and/or you learn something about how the lesson went that you would use to make adjustments.
Slide 17 Day 2: Ocean Acidification	Start of Day 2 (as written)
Slide 18 Where is all the CO_2 going? 	Show video (in folder) of where anthropogenic carbon is going into the ocean. What do you notice?

Slide 19 	This can either be a review of Day 1 (if you did it), or an introductory discussion of climate change if you are using Day 2 as a standalone lesson. The goal here is to ask students for how they would expect seasonal temperatures to change in the future using what they know about climate change. Possible answers: Warmer summers Longer summers More day-to-day variation
Slide 20 	Ask students for ideas about how carbon dioxide from the atmosphere gets into the ocean. Show video of breaking wave, if you want. (it's a very long video, so you only need to show part of it)
Slide 21 	Why does it matter that carbon dioxide is going into the ocean? Let's look at a simulation of this process. Using either a soda stream or dry ice, add carbon dioxide to water with a pH indicator in it (such as cabbage juice). Observe the color change? Additional resources for this activity in the folder.

Slide 22 	Review from Day 1. Can ask students for other thoughts based on what they just saw in the demonstration.
Slide 23 	(Yellow box says 25 on slide show) Show video. Can either watch straight through or pause to emphasize various points.
Slide 24 	Show video. Can either watch straight through or pause to emphasize various points.

Slide 25 Observations from the videos 24	Ask students to share observations from video.
Slide 26 What is happening here?  25	Optional slide if you want to go into more detail about ocean carbonate chemistry system.
Slide 27 What is happening here?  26	Optional slide if you want to go into more detail about ocean carbonate chemistry system.

Slide 28 	Introduce experiment. See additional resources in folder for options of how you could set this up and tweak it. Keep in mind that you will need to edit the slides to match what you choose to do. You will need to edit these slides based on which experimental option and equipment you will be using with students. Students have a handout to fill out with all of these questions.
Slide 29 	Students have a handout to fill out with all of these questions.
Slide 30 	Students have a handout to fill out with all of these questions.

Slide 31 	31-33. Optional bonus slides (Can also share these with the teacher) This is a good opportunity to compare global predictions of future ocean pH conditions to current pH conditions in Puget Sound. Key point: Puget Sound already experiences pH in line with the global predictions for 2095, which means that it is a really good place to learn about the possible effects of climate change on marine life.
Slide 32 	Some parts of Puget Sound already have a pH close to 7! Data from Shellfish Growers app at nvs.nanoos.org.
Slide 33 	Can use this as an exit ticket, if students have an appropriate understanding of carbonate chemistry/antacids.

Slide 34 	Can also ask a question related to this as an exit ticket.
Slide 35 	This exit ticket was designed as part of a longer unit on shellfish and aquaculture. You are welcome to design your own.

4. Pre-outreach Checklist

- Communication with classroom teacher
  - Do you know what the teacher is expecting from this lesson?
  - Do you know what students have already done or will have done by the time this lesson happens?
  - Does the teacher know what you are planning to do?
  - Have you talked to the teacher about which of the experiment options they are interested in (or if they would prefer it as a demonstration)?
  - Does the teacher know about the technology/lab equipment requirements for this lesson? For the experimental portion of this lesson, it is important to talk to the teacher about whether they have the materials to do the experiment, and in particular whether they would prefer to do a short, easily observed one or the one that involves monitoring over time.

- Materials
    - Do you know what materials the teacher has at school?
    - Do you have all the materials you need for this lesson?
        - If no, who is responsible for getting/providing the materials?
    - Who is responsible for transporting/setting up materials?