5E Learning Sequence for The Earth's Climate Constantly Changes (grades 9-12)

In the interest of time, Elaborate 2, Elaborate 3, and Evaluate 3 are not modeled in the NGSS Roll Out 2 Learning Implications High School session. These components are shaded gray in the table below.

Stage	Teacher Does	Student Does	Concept
Engage 1	Administers preassessment probe (Ice Cold Lemonade) encourage students to really explain their thinking.	Fill out a preassessment probe	The ocean has currents
Engage 2	Facilitate student discussion on what they know about oceanic currents before and after viewing a video clip of Finding Nemo in the EAC.	1) View Finding Nemo video clip of the EAC 2) Share knowledge on currents	The ocean has currents
Engage 3	Ask students to imagine the ocean was in a shoebox, what would it be like? Draw a model of a shoebox ocean, draw what you think goes in here, identify any driving mechanisms.	On chart paper, students sketch a model of a shoebox ocean and label physical features and mechanisms and provide an explanation	The ocean has currents
Explore 1	Next, break the students up into three stations: 1) Students work with two computer simulations. Students are asked to record predictions (with rationale) prior to using the simulation. If they simulation results didn't match the prediction, why do you think that is? 2) Students work with a density column (four liquids with different salinities, given the challenge of stacking all four liquids in a straw without mixing) and asked to identify which is salt water? Fresh water? Which is most dense? Least dense? 3) Students work with density boxes. Why don't the layers mix? (Unless we will have easy access to hot water, the density boxes will work with water of different salinities) Following stations, students are asked to revisit their shoebox models – using a different colored marker, update your model given what you have learned in the explorations	Rotate between three stations: 1) Computer simulations 2) Density columns 3) Density boxes as demo's Update shoebox model	Currents result from differential density of ocean water due to temperature differences and salinity differences
Explore 2	1) Start by giving students maps of warm and cold currents. Ask them to identify what the arrows represent, the different colors, and discuss what	1) Study maps of warm and cold currents 2) See video modeling global	Major oceanic currents traverse the globe and circulate thermal energy

	patterns they observe. 2) Show video clip of global conveyor belt. Describe what you are observing, what do the different shades of arrows represent? Why is some water moving on top, and some on the bottom? 3) Ask students to revisit their shoebox models – using a different colored marker, update your model given what you have learned in the explorations	conveyor belt 3) Revisit paper model	
Explore 3	Pre-build models of ocean circulation. Have students make observations before adding heat source. Ask students to predict what will happen when a heat source is added. Add heat source and have students make observations	Set up the model and observe with no heat added. Make predictions of what will happen when a heat source is added. Add heat source and observe	Scientists can model ocean circulation
Explain 1	Review what students learned in the explore 3 – explain factors such as As the oil heat's up it becomes less dense and rises, oil at the surface is cool and more dense and sinks, this models a convection current, however helps us visualize that liquid of different densities MOVES and creates currents, this model can help explain oceanic currents	Students discuss with teacher	Scientists can model ocean circulation
Explain 2	Show students the model from http://ocgweb.marine.usf.edu where scientists modeled oil spill trajectory from the deep water horizon oil spill. This is used to transition students from a classroom model of circulation to one that scientists use and to make predictions. Ask students to revisit their shoebox models – using a different colored marker, update your model given what you have learned in the explorations	Students view and discuss oil spill model Revisit Paper model	Scientists can model ocean circulation
Elaborate 1	Students work in teams and are given a clear deli container and asked to imagine that it is a system, a body of water with a set amount of energy, the walls of the container = land (like North American coast, Asian coast, etc). If this is a system, what energy is involved in	Teams build model of an ocean system and label energy added to or taken away from the system. After class discussion, teams are	To fully understand the role of the ocean in climate, scientists create models to test hypotheses of ocean circulation and oceanic changes

	the system? Students are given long, skinny post-its that are to be used to represent different types of energy. Students are asked to label the energy and use an arrow to show its direction to identify any energy added or taken away from the system. Teams then have the opportunity to walk around and view the other models in the room. When they return, they are asked if they want to make any changes to their model (and given the chance to do so). Then, the class has a discussion: • What are the sources of energy in the system? • What if any energy is being added to this system? • Where or how does that show up in your model? • Is there any energy leaving the system • Where or how does that show up in your model? • How do you make sense of this in the context of conservation of energy? • Where in the system do you see energy being transferred/changing? Teams may make adjustments to their model during the discussion. If students are missing something important from their model, redirect, "I see you have no label for energy loss to atmosphere, based on your model, the ocean is getting more energetic, but we know that's not true, they aren't boiling away". Ask students to revisit their shoebox models – using a different colored marker, update your model given what you have learned in the explorations	asked to make adjustments to their model that seem important Revisit paper model	
Elaborate 2	Teams are given a new piece of chart paper and asked turn their shoebox model into a mathematical relationship and name the variables. Give an example of a bank account to help students understand how to build a mathematical relationship Teams then share what they came up with.	Teams identify the variables in their shoebox model and develop a mathematical relationship. Teams share Teams revise mathematical	To fully understand the role of the ocean in climate, scientists create models to test hypotheses of ocean circulation and oceanic changes

	After sharing, give an example of how more variables, and variables with subscripts can be added to the relationship to make predictions and test the model. Students are asked to generate a scenario (i.e., if there were a big volcanic eruption and some solar radiation is blocked, there's a shift in a wind pattern in a neighboring ocean and more warm water enters your system, etc.) and calculate what would happen in their system. Teams then share what they came up with. Students are then shown a similar model made by an oceanographer.	relationship and provide a rationale Teams come up with a plausible scenario and calculate what would happen to their system using their mathematical relationship Teams share Students are asked to consider why oceanographers make models like this and share.	
Explain 3	The class is divided up into three teams and assigned a part of the reading, "The Role of the Ocean in Tempering Global Warming". The team is to do the following: - Section 1 including "where is the increasing heat coming from" - Section 2 "So where is the recent surface warming" - Section 3 "what explains slowing rates of surface warming" Identify the three big ideas from your section of the reading – the team must reach consensus on what constitutes, big ideas. Be prepared to walk the whole group through your graph, what it means, and give us an example of how to interpret You may use your web device to look up anything (like acronyms) you don't understand. As teams share, students are asked to record notes for themselves.	Team read "The Role of the Ocean in Tempering Global Warming" Paper model	Ocean circulation drives global weather patterns
Evaluate 1	Students are asked to individually take three post-its. One post-it will be placed on a wall labeled "Square", on this post-it, they are to identify anything that squares	Students create a square, circle, and triangle post it and place on designated walls in the classroom.	Ocean circulation drives global weather patterns

	with their thoughts (something that makes sense to them). The second post-it will be placed on a wall labeled "Circle", on this post-it, they are to identify anything they are having a hard time wrapping their mind around (something confusing them). The third post-it will be placed on a wall labeled "Triangle", on this post-it they are to identify three most important points from the information they are learning. Take time to read the post-its as they will reveal student understanding, or lack thereof (and allows them to see the thinking of their peers as well). If there are common areas of problems, address these questions with the whole class and/or redirect instruction if necessary (unless you anticipate the next two extends will provide a vehicle to answer the questions)		
Elaborate 2	Students are asked to use their map of warm and cold currents and compare it against to others: Land & Ocean Temperature Departure from Average Jan-Dec 2014 and Land-Only Precipitation Percentiles Jan-Dec 2014 Have a discussion with the class to make sure they understand the maps (i.e., what is "departure from average") Have teams determine any patterns they notice and chart Have different teams choose a different location in the world and, using a web device, find out what the current ocean temperature is for the area and land-based temperature for a city (this is fairly easy to find by Googling specific locations and "ocean temperature", etc. If the task is too challenging, stick to US area as NOAA provides buoy data.) If time allows, gather multiple temperatures for the area and generate an area	Teams do a map comparison and determine any patterns which are charted. Using a web device, students choose a location they would like to know more about and search for the current ocean temperature and land-based temperature. After noting class findings, chart patterns. Consider what is happening to energy in the system, chart responses Students then share what they know about specific ocean events that drive weather events.	Ocean circulation drives global weather patterns

	average. Compare class findings and determine if there are any patterns. Chart responses. Students are asked to consider what is happening to energy in the system, chart responses. Have a discussion on what students now about how the ocean drives weather events (like El Niño, hurricanes, lake effect, etc.) A good report for teacher background reading: http://www.ncdc.noaa.gov/sotc/global/		
Elaborate 3	Students are asked to use the "Key Message 8: Changes in Hurricanes" the connection between an increase of thermal energy in the oceans and hurricane intensity, frequency and duration. At a team, students are asked to connect something they learned from the reading to what they've been exploring about energy and ocean circulation. They are asked to take this and add it to a class chart where all of the ideas are written.	Students read article Teams of students decide something they have learned to connect new information from the reading to what they've been exploring about energy and ocean circulation. Team representatives add their idea to a class chart	Ocean circulation drives global weather patterns
Evaluate 2	Beginning with the explore portion of the 5E (once the concept of "energy" emerges), students are repeatedly asked the following questions: What kind of energy do you have at beginning? What goes out? What are the types? Where did it go to? How does what we have just done change your thinking? How does this part effect your model? (keep revisiting model throughout) At the end of the lesson sequence, students are asked to provide a rationale for their final model to show their understanding of what they learned in the series of activities. They are also asked to consider how the model speaks to the phenomenon of the rip current and the Finding Nemo EAC clip.	Students discuss, build a revised paper model and provide a rationale for the final model	
Evaluate 3	Students are asked to go back to their pre-assessment	Students revisit their pre-	

	probe. Mention that their original thinking is important, so we will leave it on the paper. Re-read the probe. Using a different colored pen, how would you now answer? What changes would you make? How can you now elaborate on your original answer? Identify on your paper that this color is now your new thinking.	assessment probe and edit responses.	
Evaluation is also happening throughout the entire 5E and the teachers listens to student conversations and monitors work			

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Resources for Engage

- Finding Nemo EAC video clip http://video.disney.com/watch/catching-the-eac-4bb39d25a179ea8833003b15

- Keeley, P., Eberle, F., and Tugel, J. Ice-Cold Lemonade "Uncovering Student Ideas in Science, Volume 2: 25 More Formative Assessment Probes, NSTA Press, 2007

Resources for Explore

- Ocean simulations: http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-simulation-activities#heatenergy

- Density Boxes: http://www.di-mac.com/Waterdensity.html

- Map of warm and cold currents http://www.ces.fau.edu/nasa/images/module_3/surface_currents_lg.gif

- Global conveyor belt video http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3658

- Ocean circulation model http://www.sciencebuddies.org/science-fair-projects/project_ideas/OceanSci_p012.shtml#summary

- Oil spill model http://ocg6.marine.usf.edu/~liu/Drifters/latest_roms.htm

Resources for Explain

- The Role of the Ocean in Tempering Global Warming reading http://www.climate.gov/news-features/blogs/enso/role-ocean-tempering-global-warming

Resources for Extend

- Key Message 8: Changes in Hurricanes reading (pages 41 and 42 of this report) http://s3.amazonaws.com/nca2014/low/NCA3_Full_Report_02_Our_Changing_Climate_LowRes.pdf?download=1