NGSS Lesson Implications: Grades 9-12

Objective: To experience an overview of how a sequence of planning tools (specifically, the conceptual flow, learning outlines, and 5E learning sequence) provide a framework for NGSS aligned classroom planning illustrating how Science and Engineering Practices and Cross Cutting Concepts deepen understanding of Disciplinary Core Ideas.

Time:

Total Time		**3 Hours**
Part I	Welcome and Session Goals	10 minutes
Part II	Overview of the Learning Experience	15 minutes
Part III	Inside the box: experiencing the 5E	125 minutes
Part IV	Outside the box: debrief	30 minutes

Materials: Slides

S1	NGSS Lesson Implications
S2	Session Goals
S3	Learning Experience
S4	Outside the Box
S5	Tool D: From Conceptual Flow to Learning Outline to 5Es
S6-8	Conceptual Flow
S9-11	Preliminary Learning Sequence
S12	Inside the Box
S13	What do you know?
S14	What do you know? Observe the phenomena
S15	Catching the EAC
S16	Debrief
S17-18	Shoebox Model
S19	Investigation #1
S20	Revisit Shoebox Model
S21	Investigation #2
S22	Investigation #3
S23	Revisit Shoebox Model
S24-25	Investigation #4
S26	Modeling Oceanic Circulation
S27	Scientists Regularly Model Oceanic Circulation
S28	Time to Model Like an Oceanographer!
S29	Brainstorming Sources of Thermal ENergy
S30	Build a Model
S31	Thinking about the Models
S32	Think about just the thermal energy in your model
S33	Shoebox model → mathematical relationship
S34-35	Mathematical Relationship? What?!?
S36-37	Shoebox model → mathematical relationship
S38	Testing your model!
S39	Testing the model
S40	Your Bruno Mars obsession would change your bank account

S41	BUT your Bruno Mars obsession also has its perks!
S42	In real life, mathematical relationships can take into account a lot of variables!
S43	Testing your model!
S44	Turns out, scientists do the same thing you have been doing!
S45-46	An Oceanographers model
S47	An Oceanographers model *hidden under* Did your brain just explode
S48	Why model?
S49	How does the ocean drive weather patterns?
S50	Earth's average surface temperatures since 1970
S51	Changes in Earth's annual heating rate from 1985-2013
S52	Changes in ocean temps from 1971-2010 for depths from 0-700 meters
S53	Consider what you've been learning about the ocean and weather patterns
S54	Revisit Ice Cold Lemonade
S55	Outside the box
S56	What were the 5E components?
S57	5E learning sequence
S58	Debrief some more
S59	Tool D: From conceptual flow to learning outline to 5Es
S60	Reflection 3-2-1

Handouts

H1	High School Conceptual Flow
H2	Preliminary Learning Sequence Days 4-7
H3	Ice Cold Lemonade
H4	Investigation #2 (Map of currents) **(print in color)**
H5	The Role of the ocean in tempering global warming
H6	5E Summary
H7	Full 5E Learning Sequence for The Earth's Climate Constantly Changes

Charts

C1	Parking lot: general session questions
C2	SEP and CCC are front and center
C2	phenomenon Observations
C3	Phenomenon Questions
C4	Square
C5	Circle
C6	Triangle

Resources

R1	Density Column Challenge (for trainers reference only)
R2	Density Boxes **(print 3 copies in color and place in sheet protector to place at stations)**

R3	Computer Simulations **(print 3 copies in color and place in sheet protector to place at stations)**
R4	Thermohaline Circulation (for trainers reference only)
R5	Mini Ocean Simulation **(print 3 copies in color and place in sheet protector to place at stations)**
R6	Ice Cold Lemonade (for trainers reference only)
R7	HS-PS3-1 with evidence statements (for trainers reference only)
R8	HS-ESS2-4 with evidence statements (for trainers reference only)
R9	SEP: Mathematical and Computational Thinking (for trainers reference only)
R10	CCC: Systems and System Models (for trainers reference only)
R11	CCC: Energy and Matter (for trainers reference only)
R12	CCC: Cause and Effect (for trainers reference only)
R13	Constructivism and Conceptual Change 1
R14	Constructivism and Conceptual Change 2

Other

- Internet access will be essential for this session!
- To host location: In addition to participant handouts, please print 3 copies of R2, R3, and R5 in color and place each in a sheet protector for station directions
- If possible: does the host location have 3 laptops that could be used? The simulations in the Explore 1 activity need to be downloaded prior (it would save time not having participants do this – please see directions below under "Advanced Preparation", step 3 part D
- Chart paper
- 1 pack of mulit-colored markers per team of 6 people
- 1 Sharpie/permanent marker for each team of 6 people
- Regular post-it notes for each team (any color is fine)
- 1 in x 3 in pad of post-it notes for each team (if unable to get, we can trim regular post-its)
- 1 pair of scissors for each team of 6 people
- Colored pens, one for each participant (not blue or black)
- Lots of water!
- Pitchers for moving water around (2-3)
- 28 empty 16 oz water bottles (pulled from the recycle bin) are very helpful!
- Plastic cups (12)
- Clear plastic straws (24)
- Food coloring (4 colors x 4)
- Pickling salt or kosher salt (large box)
- Rags for water spills
- Density boxes (3)
- Ice (or a heat source to warm water)
- Cafeteria trays to catch water spills (6) – should be long enough to accommodate the density box (28 cm or 11 in)

- 1000ML beaker (500ML can work if 1000ML is not available) or 2-qt or 1.5-qt clear pyrex baking dish (3)
- Thyme, dried (1 bottle)
- One pair of leather work gloves (to grab hot items after use)
- Teaspoon (1)
- Vegetable oil (about 24 cups)
- Funnel
- Container to dispose of used oil
- Paper towels (to wrap oily glass after use – unless these can be washed on site)
- Large bags (large enough to hold glass after use – unless these can be washed on site)
- Small candles (3 if larger candles, or 9 tea light candles/team)
- Matches or lighter for lighting candles
- Something to elevate glass above candle (3 ring stands with mesh base/team or other elevating objects – see directions **R4**)
- One large clear plastic deli storage container with lid per team
- Do we need to have a fire extinguisher in the room?

Advanced Preparation:

1. Things to print for each participant:
   - H1 High School Conceptual Flow
   - H2 Preliminary Learning Sequence Days 4-7
   - H3 Ice Cold Lemonade
   - H4 Map of warm and cold currents (in color)
   - H5 The Role of the ocean in tempering global warming
   - H6 5E Summary
   - H7 Full 5E Learning Sequence for The Earth's Climate Constantly Changes

2. Directions to color print and laminate for stations
   R1: Directions for Explore 1: density columns (3)
   R2: Directions for Explore 1: density boxes (3)
   R3: Directions for Explore 1: computer simulations (3)
   R4: Directions for Explore 3: Mini Ocean simulation (3)

3. Things to prepare, review or read:
   a) Review HS-PS3-1 (including evidence statements), DCI: PS3.b, SEP: Mathematical and Computational Thinking, and CCC: Systems and System Models. (The CCC's energy and matter and cause and effect are also quite prominent in this session, although not "tagged" with the PE in the standards. It would be beneficial to review these as well.)
   b) Just before participants enter the room, open Catching the EAC link at **S15 (Catching the EAC**) and advance through the advertisement, then pause video so that it is it ready to go.
   c) Review directions for Explore 1 (Density columns) that you will direct participants to at **S19 (Investigation #1)** and pre-make 3 sets of 3 different salt solutions and set up stations:

a. 9 Empty 16 oz water bottles work perfectly for this! If unavailable, use cups for the solutions.
b. In three bottles, add fresh water and a few drops of blue food coloring.
c. In three bottles add about 1 tsp of salt, water (warm water will work better at dissolving the salt), and a few drops of yellow food coloring
d. In three bottles add about 2 tsp of salt, water (warm water will work better at dissolving the salt), and a few drops of red food coloring
e. You will be setting up three stations around the room. Each station should be set up with items on a tray to catch spills, one of each solution of water, a few empty cups (participants like to use these as they tinker with the solutions), a few clear straws, and **R1 Directions for Explore 1: Density Columns** station directions.

More info on this activity:
http://www.stevespanglerscience.com/blog/experiment-of-the-week/salt-water-density-straw-sick-science/

d) If 3 laptops are available for presenter use, pre-download the simulations to laptops for the Explore 1 activity that you will direct participants to at **S19 (Investigation #1)**. If no extra laptops are available, download onto the presenter computer (the participants will have to share using the projected screen).
  a. Download two simulations: http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-simulation-activities#heatenergy
    1. Computer settings might now allow the download, go into the computer's security settings and allow the download. (Mac versions of the simulations can be found in the dropbox folder: 6.0 Tool 9-12> Resources Tool 9-12 > mac versions of computer simulations)
    2. Under Heat energy and moving molecules: download the first simulation called, Rising Temperatures.
    3. Under Density of liquids and ocean currents, download the second animation called, Model Ocean Animations
  b. Set up the computers at three different places in the room.
  c. Place R1 Directions for Explore 1: Computer Simulations at each computer

e) Review directions for Explore 1 (Density boxes) that you will direct participants to at **S19 (Investigation #1)** and pre-make three sets of a cold water solution and room temperature water solution and a salt water solutions for each stations.
  a. Get water at two different temperatures (room temp water dyed blue and water chilled on ice dyed green is fine) and prepare a

fresh-water solution (blue) and a salt-water solution (yellow). Salt water solution: mix about 1 tsp of salt for 16 oz water.

b. You will be setting up three stations around the room. Each station should be set up with items on a tray to catch spills, one of each solution of water, a the clear density box, and **R1 Directions for Explore 1: Density Boxes** station directions.

c. You will need a pitcher or large container in which to dump "used" liquids between each trial.

Density boxes can be acquired at http://www.di-mac.com/Waterdensity.html
A video showing the density box in use can be found here: https://www.youtube.com/watch?v=RFiriyuqoeY

d) Review directions for Explore 3: Mini Ocean simulation that you will direct participants to at **S25 (Investigation #4)**. If possible, pre-build for participants:

a. Set up a ring stand to sit just above a candle.
b. Place the wire gauze square on the ring
c. Place a 500ML or 1000ML beaker on the wire gauze
d. Sprinkle in about 1tsp of a dried herb
e. Pour in vegetable oil (the exact amount isn't important, but you should fill it high enough that you have a good column of oil
f. If necessary, use a straw to mix the herb in the oil

It is possible that you might find oil with the herb pre-mixed from another session. We will try to re-use so we don't waste oil!

g. Ideally, 8 of these stations will be set up around the room (one for each table). Given the table space, it might not be possible to set these up on tables, but at another location in the room and then transferred to tables when ready to use.

More information on this can be found at: http://www.sciencebuddies.org/science-fair-projects/project_ideas/OceanSci_p012.shtml#summary

5. Read **R4 Thermohaline Circulation**. **S22 (Investigation #3)** requires you to play a simulation for participants. You may want to test simulation ahead of time to see that your computer can play the simulation from the powerpoint (you may need to download to your computer. http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3658

6. Read background notes for R6 Ice Cold Lemonade - many adult participants hold misconceptions on this topic

7. If you want to play Uptown Funk (Mark Ronson and Bruno Mars) for participants at **S43 (Testing your model!)**, you can download from iTunes: https://itunes.apple.com/us/album/uptown-special/id943946661 (I added a

hyperlink to the song, but not sure if it will work on other computers without downloading the song)

8. It is recommended that the co-presenter act as the "teacher voice" in the room when participants are experiencing the 5E as students. The co-presenter can explicitly point out some of the strategies being used, which phase of the 5E they are engaging in, etc. This has not been scripted, so it's advised that presenter teams review this script together prior to the session and agree on where this would benefit the participants.

9. Charts to make:

C1	Parking lot: general session questions (post before session starts)
C2	Rules of Engagement (see first box, post before session starts)
C3	SEP and CCC are front and center (see second box post before session starts)
C4	Session Concepts (see third box, post before session starts)
C5	phenomenon Observations (build with participants at **S15, Catching the EAC**)
C6	Phenomenon Questions (build with participants at **S15, Catching the EAC**)
C7	Square (post at **S55, Consider what you've been learning about the ocean and weather patterns**)
C8	Circle (post at **S55, Consider what you've been learning about the ocean and weather patterns**)
C9	Triangle (post at **S55, Consider what you've been learning about the ocean and weather patterns**)

Rules of Engagement

- No one teaches; everyone facilitates
- Listen more than you speak
- Everyone here is smart; everyone has something valuable to say
- Don't steal anyone's "aha" moment
- No one in the room knows everything but everyone knows something

Science and Engineering Practices
and
Cross Cutting Concepts
Front and center

SEP: Mathematical and Computational Thinking

CCC: Systems and System Models

What others emerge in the lesson?

Session Concepts

- To fully understand the role of ocean in climate, scientists create models to test hypotheses of ocean circulation and oceanic changes.
- Ocean circulation distributes energy and drives global weather patterns

Procedure:

Part I Welcome and Session goals (10 minutes)

1. Display **S1 (NGSS Lesson Implications: High School)** and welcome participants to session. Briefly introduce presenters and for information about participants (i.e., how many of you are current high school teachers? Who currently teaches _____?)

2. Display **S2 (Session Goals)** and review the goals on the slide

Trainer Note. The SEP and CCC are at the "front" of this lesson, the DCI's then emerge as students move through the phases of the 5E.

Part II Overview of the Learning Experience (15 minutes)

1. Display **S3 (Learning Experience)** and explain that part of our session we will be examining the learning experience from outside the box (From the teacher's perspective) and part of it from inside the box (as the student would experience in the classroom).

2. Occasionally, when we are experiencing from inside the box, the co-presenter will take the perspective of outside the box and point out some of the strategies being used to make it explicit.

3. Display **S4 (Outside the box)** – we are starting by examining this from the teacher's perspective.

*Trainer Note. As participants raise questions, which may start here, create a "parking lot" on chart paper, **C1 (parking lot: general session questions)** that these questions can be added to. By the end of the session, we will try to address these questions.*

4. Display **S5 (Tool D: From Conceptual Flow to Learning Outline to 5Es)** and walk participants through the planning structure we are using. From the completed conceptual flow, we will select a portion for the learning sequence which is a rough idea outline of instruction over a multi-day period. From this, a section of the preliminary learning sequence is used to develop a 1 to 5 day 5E Learning Sequence (which participants were introduced to in the previous session).

5. Display **S6 (Conceptual Flow)** and let participants know they will get a copy of the flow at the end of the session. Ask participants what they remember about the development of the flow from Tool 1 Roll Out 1 and the "big" idea for the unit, and how concepts support the big idea

*Trainer Note. Decide if you want to pass out, **H1 (Conceptual flow)** to participants now or at the end of the session. If you have a very attentive group, it's probably fine to pass out now. If not, consider waiting until the end as this might distract participants at this time – we are short on time and want to move through modeling the 5E*

6. Display **S7 (Conceptual Flow)** which shows PE's and DCI's – ask participants what they remember about the placing these into the flow (remember that codes with dashes are the PE, and codes with dots are the DCI). This particular conceptual flow highlights PE's from Earth and space science (ESS), physical science (PS) and engineering (ETS). There would be natural connections to life science as well, but these have been left off to avoid brains from exploding too much.

7. Display **S8 (Conceptual Flow)** and mention that this shows the section of the flow we will be working with in this session

8. Display **S9 (Preliminary Learning Sequence)** and discuss how the teacher uses this tool to outline the sequences leading to a 5E. Walk participants through the structure

9. Display **S10 (Preliminary learning sequence)** – which includes concepts from the second column in the conceptual flow - Mention that this is how you would place your concepts into the table

10. Display **S11 (Preliminary learning sequence)** – a filled out version of Days 4-7 and distribute **H2 (Preliminary Learning Sequence)** walk participants through the structure. You can point to **C2 (SEP and CCC are front and center)** as a reference and ask participants to refer to this throughout the session and to think about other CCC that they can recognize (even though they weren't explicitly "targeted" by the PE we are working with).

Part III Inside the box: experiencing the 5E (125 minutes)

1. Display **S12 (Inside the box)** – we are now going to experience the 5E from the student's perspective, modeling a classroom experience.

Trainer Note. Do not give content instruction during the Engage phase(s) of the 5E – only procedural directions and probing questions

Once we move inside the box, be really explicit that this lesson is for high school students – we are trying to tap into <u>their</u> world and <u>their</u> experiences and help reveal the content for them by putting the SEP and CCC front and center in the lesson. Choices like using the clip from Finding Nemo, giving them a kinesthetic experience with the mathematical reasoning, and Bruno Mars reference might be lost on adults, but is designed to help kids relate to the content. We also don't *know if this lesson will be taught to 9th graders or 12 graders, the experience needed to be for all high school students.*

2. Display **S13 (What do you know)** and pass out **H3 (Ice Cold Lemonade).** Ask participants to individually read the prompt carefully and take time to identify their thinking in writing. Ask them to keep it private and that we will come back to this at the end of the session. **Engage 1 (concept: the ocean has currents)**

3. Display **S14 (What do you know? Observe the Phenomena)** and let participants know that we want them to observe the phenomena, record observations in their notebooks, and develop a list of questions with their partner.
   a. show **S15 (Catching the EAC),** click on the hyperlink to show a video clip from Finding Nemo, and give participants a moment to record observations/questions. **Engage 2 (concept: the ocean has currents)** Link: *http://video.disney.com/watch/catching-the-eac-4bb39d25a179ea8833003b15*
   b. Then show **S16 (Debrief)** and ask participants to share observations
   c. and chart **C3 (phenomenon observations)** and Questions and chart **C4 (Phenomenon questions).**

4. Display **S17 (Shoebox Model)** ask participants to consider the scenario and discuss with their team **Engage 3 (concept: the ocean has currents)**

5. Pass out a piece of chart paper and a pack of markers to each team. Display **S18 (Shoebox Model)** and go over directions with participants, clarify if necessary. Monitor participants as they build their model to make sure they are labeling and explaining. As our PE centers around the idea of energy, some questions you might consider asking include: What kind of energy is in your system? Does it come from somewhere? Does it go anywhere? **Engage 3 (concept: the ocean has currents)**

Trainer Note. Participants will be building a paper model (diagram with descriptions) throughout the next several experiences to show their understanding of energy in an ocean system. This will later develop into a physical model, and then into a mathematical relationship. Remember that in NGSS, "Models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others. Students can be expected to evaluate and refine models through an iterative cycle of comparing their predictions to the real world and then adjusting them to gain insights into the phenomenon being modeled." "Modeling in 9-12 builds on K-8 experiences and progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s)."

Trainer Note. Do not give content instruction during the Explore phase(s) of the 5E – only procedural directions and probing questions

6. Display **S19 (Investigation #1)** and go over directions with participants. Direct 1/3 of each team to begin at station 1 (heat/energy computer simulations, R3), 1/3 to station 2 (density column challenges, R1), and the remaining group to station 3 (density boxes, R2). Participants will follow directions posted at each station and do in the activity. If no computers for participants are available, use the presenter computer and project the simulations. **Explore 1 (concept: currents result from density of ocean water due to temperature differences and salinity differences)**

Trainer Note. There is not time for participants to experience all three stations (as we need to spend quality time developing the mathematical relationship later and debriefing the 5E). Encourage participants to use their mobile devices to take photos of what they did to help with conversations back with their team when they share out whole group. You can explain that as a teacher, they would decide to either do this or experience all 3 stations before moving on – what are the merits of each? It's also good to point out that these weren't done as whole-group demo's, the 5E model calls for giving students hands-on experiences to make sense of information.

For the density boxes, encourage teams to experiment with a variety of different pairs of liquids (room temp vs. cold, fresh vs. salty, partial salty vs. fresh or salty). Each station should have a container in which to dump their mixed solutions between trials.

7. Display **S20 (Revisit Shoebox Model)** and ask participants to consider what they have just learned and revise their shoebox model they made on their chart. Ask participants to use a different colored marker. As participants work, ask them to write a rationale for their changes.

8. Display **S21 (Investigation #2)**, go over the slide and handout **H4 Investigation #2 (Map of currents)** give participants a moment to discuss the image and share out. Participants should be able to identify the following:
   a. Arrows represent currents
   b. Black arrows are cold currents, red arrows are warm
   c. There is an overall pattern of warm currents moving from the equator to the poles, and cold currents moving from the poles to the equator
   d. There is an overall pattern of warm currents moving along the western edges of continents and cold currents moving along the eastern edges.

   Explore 2 (concept: major ocean currents traverse the globe and circulate thermal energy)

9. Display **S22 (Investigation #3)**, hover your mouse over the image and press play to let participants view the simulation of the ocean conveyor belt. While viewing, ask participants to describe what they are watching: what do the different shades of arrows represent? Why is some water moving on the surface and some on the bottom? Encourage notebook entries. If you are having trouble with playing the simulation, the URL is in the notes box on the PowerPoint **Explore 2 (concept: major ocean currents traverse the globe and circulate thermal energy)**

*Trainer Note. Review **R4 (Thermohaline circulation)** for information on this simulation. At this stage in the 5E, do not give direct instruction, participants should be able to comment that the arrows represent ocean currents, surface currents would be less dense (warmer, less saline) than deep currents (cooler, more saline). Facilitate their understanding by asking probing questions such as, "Why do you think the water sinks at Greenland?"*

10. Display **S23 (Revisit Shoebox Model)** and ask participants to consider what they have just learned and revise their shoebox model they made on their chart. Ask participants to use a different colored marker than the previous 2 times they worked with the model. As participants work, ask them for a rationale for their changes.

11. Display **S24 (Investigation #4)** and have a representative from teach table gather the materials from the materials table and bring back to their table. Have participants follow the first set of directions, R5 for setting up the model, then make a prediction about what will happen when we add a heat source. After predictions, and getting hypothesis approved (*SUGGESTION: teams earn matches only after showing the Trainer the hypothesis. Look for statements that are explanations (example: I think the oil will…. I think this happens because….)* display **S25 (Investigation #4)** and have participants light their candles, discuss and record observations, and have teams discuss an explanation. Be explicit with the following:

   a. Differential heating leads to convection and currents.
   b. IMPORTANT: This is the part of the lesson where it will be the most apparent that the direction of movement is from HOT → cold (make sure this comes out in participant discussion as it connects to the Ice Cold lemonade probe)
   c. In the ocean, there is not just one current, but a SYSTEM of currents (CCC) – remind participants of the global conveyor belt simulation viewed in **S22** that modeled this.

Explore 3 (concept: scientists can model ocean circulation)

12. Display **S26 (Modeling Oceanic Circulation)** and ask teams to share their thinking. At this point, confirm ideas in the room such as:
   a. As the oil heat's up it becomes less dense and rises
   b. Oil at the surface is cool and more dense and sinks

c. This models a convection current, however helps us visualize that liquid of different densities MOVES and creates currents
d. This model can help explain oceanic currents

Explain 1 (concept: scientists can model ocean circulation)

Trainer Note. Safety issue with heat source – make sure set-up is on a stable surface and that all flammables are away. *Many teams will observe a convection current (oil rising from the heat source to the cooler top of the container, and then spreading out). You can also ask questions to help participants link their observations to what they see in the video (ex: the herb does not fall until it hits the sides of the container, much like a current will plunge after impacting a land mass). There most likely is not time for this, but if ice is available in the room, some teams may ask to explore what happens if you "chill" part of the ocean by holding ice to the outer wall of the beaker and make observe the oil and thyme plunging faster.* *Trainer may wish to revisit Ice Cold Lemonade here rather than at the end of the session as this was the most directly related content experience to the scenario in the probe (see slide 54)*

13. Display **S27 (Scientists regularly model oceanic circulation)** and review the first part of the slide – participants should already be familiar with temperatures and salinities from the activities.
    a. Explain that topography takes into account the physical features of the ocean floor, surrounding land, etc. Wind patterns also have a big influence on ocean water as it pushes surface water.
    b. Click on the hyperlink http://ocg6.marine.usf.edu/~liu/Drifters/latest_roms.htm to view a Deepwater Horizon oil spill trajectory that was used to predict the path the oil spill would take in the Gulf of Mexico in 2010. Click on "play" (under "animation control") to see the predicted path. Note the text under the animation for clarification.

Explain 2 (concept: scientists can model ocean circulation)

Trainer Note. There are other factors that influence too, such as gravity, solar surface heating, Coriolis effect that we aren't addressing in this 5E

14. Display **S28 (Time to Model Like an Oceanographer)** pass out clear deli containers and a sharpie/permanent marker to each team. Ask participants to:
    a. now think of their shoebox model as this container.
    b. label two opposing sides as land masses (i.e, North America on the left, Europe on the right).
    c. Label the other sides as water inputs (i.e the top as input from the artic, the bottom as input from the south Atlantic).

d. Think of your box as a system and decide what things influence thermal energy in the system and record in your notebook

Elaborate 1 (concept: to fully understand the role of the ocean in climate, scientists create models to test hypotheses of ocean circulation and oceanic changes)

Trainer Note. Listen to conversations about this – participants should be able to think of things like energy from the sun, warm current coming from the equator, cool current coming from the pole, glaciers, etc.

15. Display **S39 (Brainstorming Sources of Thermal Energy)** Facilitate a brain storming session about sources of thermal energy, encourage participants to revisit their paper shoebox models. Ask participants if they can think of other sources of thermal energy identified on the models of other teams, information from the investigations, etc.

16. Display **S30 (Build your Model)** This should be done as teams. Using long skinny post-its (if no long skinny post-its are available, cut a standard sized post-it into thirds to create these), label the things that influence thermal energy in their system. Arrows on the post-it identify the direction. When complete, have teams do a gallery walk to see what other models look like, then return and revise theirs.

    Possible modification: In lieu of the gallery walk, have a representative from each team contribute an "arrow" to a box in the front of the room to make a class model.

    In PD sessions with a time crunch, this can done as a demo – but be explicit with participants that high school students should work on this as teams but because of time this will be modeled whole group. Help participants understand that this would benefit kinesthetic learners and help students isolate the sole variable of thermal energy components of their paper models.

17. Display **S31 (Thinking about the Models)** and facilitate a group discussion using the prompts on the slide.

18. Display **S32 (Think about just the thermal energy in your model)** and ask what is meant by "energy". Confirm that we are really thinking about thermal energy in our model. With this in mind, we are going to further develop our model

19. Display **S33 (Shoebox Model → Mathematical Relationship)** Pass out a new piece of chart paper to each team. Have the team start by thinking of all of the sources of energy (energy variables) in their model and to turn them into a mathematical relationship that they will then share.

Trainer Note. Slides 34-36 and 39-41 are intended to be a scaffold to help students understand how they might develop a mathematical relationship from variables. Also, we do assign units when working with numbers, but don't worry too much about this at this stage as we are trying to simplify things to help students develop the idea of using variables to account for inputs and outputs in the system.

20. Display **S34-S35 (Mathematical Relationship? What?!?)** and go over the scenario on the slides with participants. The slides are intended to help students understand how we can assign a letter value to variables.

21. Display **S36-S37 (Shoebox Model → Mathematical Relationship)** Give participants time to develop their relationships on chart paper. Have a few teams share, and encourage teams to revise if necessary.
    Elaborate 2 (concept: to fully understand the role of the ocean in climate, scientists create models to test hypotheses of ocean circulation and oceanic changes)

22. Display **S38 (Testing your Model)** and read the prompt with the group. **S39-S41** then walk participants through the slides which provide an explanation of how we can test our mathematical relationship with various "scenarios", giving the model predictive power and introducing variables with subscripts. Some adult groups will easily take to this task and add a lot more to their mathematical model. When monitoring them, encourage them to just think about "inputs" (as we will be scaffolding "outputs" and subscripts next).

23. Display **S42 (In real life, mathematical relationships can take into account a lot of variables!)** and ask participants to suggest other variables and share (such as: big volcanic eruption blocks some solar radiation, there's a shift in a neighboring ocean's wind pattern and more warm water enters your system…)

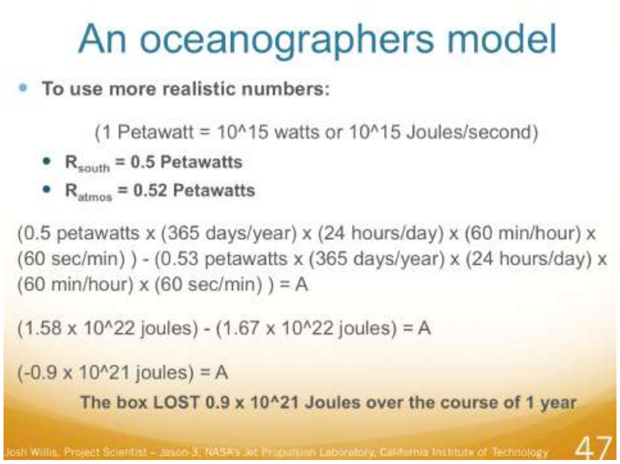
24. Display **S43 (Testing your Model!)** and have participants choose a variable/scenario and how that would impact their mathematical relationship – work this out on the chart paper and share

25. Display **S44 (Turns out, scientists do the same thing you've been doing!)** and read slide

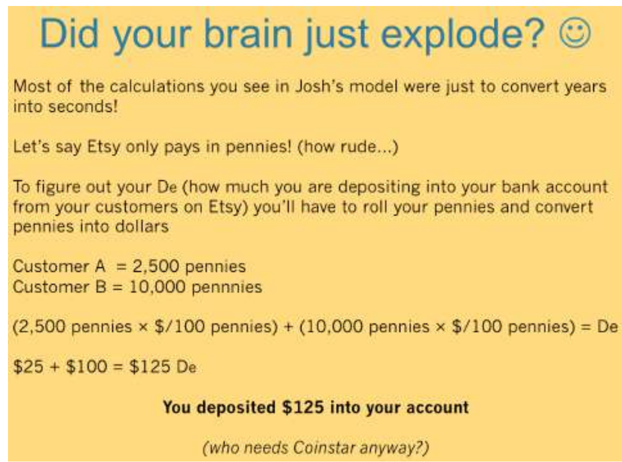
Continue to next page

26. Display **S45-S46 (An Oceanographers Model)** and walk participants through Josh Will's model of the North Atlantic.

Trainer Note. The purpose of Josh's model, slides 45-47 is so students can see a mathematical relationship similar to what they were working on. Actual oceanic "shoebox" models get much more complicated than this, but here Josh provides a good way for student's to wrap their head around the concept. In field testing slide 47, participants are initially overwhelmed until they realize that most of Josh's math is to convert years into seconds. An animated box will help you walk participants through a scaffold using the analogy of the Etsy shop paying in pennies, and how to convert pennies into dollars. Following the scaffold, Josh's model will appear again (an animation will remove the box).



S47 Before animation



S47 After animation

10. Display **S47 (An Oceanographers Model *hidden under* Did your Brain Just Explode)** to view this slide as participants will see it, go into slide show in PowerPoint. You will see Josh's more accurate model first, then using animations, a text box that reads, "did your brain just explode" that will overlay and allow you to walk participants through a scaffold of understanding conversions. A final animation will remove the yellow box and reveal Josh's more accurate model again. After participants have had time to process, ask participants to discuss with their team why they think scientists like Josh make models like this.

11. Display **S48 (Why Model)** and ask participants to discuss with their team why they think scientists like Josh make models like this

12. Display **S49 (How does the Ocean Drive Weather Patterns)** and pass out **H5 (The Role of the Ocean in Tempering Global Warming)** to each participant. Have the room divide up the article, one team will do section 1 (part 1 including "where is the increasing heat coming from"), another part of the room do part 2 ("so where is the recent surface

warming") and the remaining part of the room do part 3 ("what explains slowing rates of surface warming"). Go over directions on the slide, listen to team conversations, and share out. **Slides 50-52** include the graphs the teams will discuss in case it is helpful to have them projected.
Explain 3 (concept: Ocean circulation drives global weather patterns)

Trainer Note. Some participants may challenge the article and ask if you would "really give it to students". It may be helpful to mention that it's good to challenge students (and don't underestimate them). If the prompts on the slide don't seem adequate, how else would you provide supports to help students understand the article? How could break the reading up into manageable chunks? How could you question students and debrief with them. You might spend more than one day breaking down the article into something more digestible.

Science professors at the university level often lament that students are unable to access the reading required in their general courses. The NOAA article is intended for the public, and is a piece that can be used to start helping high school students start working with such sources of information. Yes, it might be hard, but we need to give our students these experiences, with adequate support as needed.

13. Display **S53 (Consider what you've been learning about the ocean and weather patterns)** Post three different pieces of chart paper around the room (**C5, C6, C7**). Label one "Square", another, "Circle", and the third, "Triangle". Pass out post-it notes to participants and ask them to take a post it for each shape and follow the directions on the slide. Have participants put their square post-it on the square chart, etc. Take time to read the post-its. If there are common areas or problems, address these questions with the whole class and/or redirect instruction if necessary (unless you anticipate the next two Elaborates will provide a vehicle to answer the questions)
Evaluate 1 (concept: Ocean circulation drives global weather patterns)

Trainer Note. Because of time, the next two elaborates and Evaluate 2 are not included in this presentation. See H6 (Full 5E Learning Sequence for the Earth's Climate Constantly Changes) for more information on these. You'll identify these in the gray shaded rows

Display **S54 (Revisit Ice Cold Lemonade)** Ask participants to find their Ice Cold lemonade hand-out (**H3**), re-read the prompt, and revise their work. Ask them to make revisions in a different colored ink, we will keep visible to honor their original thinking. Have participants share their thinking when done so you can check that the thinking is aligned with how scientists think about the transfer of energy (presenter: read **R6** prior). Emphasize that heat moves from hot to cold. You can remind them that the convection model we did with the oil and candle showed this.

Evaluate 3 (all concepts)

Part I *Outside the box: debrief* *(30 minutes)*

1. Display **S55 (Outside the box)** Explain that we are going back to examining this from the teacher's perspective.

2. Display **S56 (Where were the 5E components)** Using their chart, ask participants to identify which parts were the Engage, the Explain, etc. Acknowledge that this particular 5E was in no way linear, this was a huge topic, but can they identify something that would fit the various components? Have participants share ideas and then share **S57 (5E Learning Sequence)** and pass out **H6 (5E Summary).** Point out that to save space the "Teacher does" and "Student" does columns are shrunk. Help them understand that to scaffold the concepts, we repeated multiple portions of the 5E, but the integrity of starting with an Engage came first, various explores were followed by explains and elaborates, and final Evaluations didn't happen until the end. Also point out that throughout the entire 5E the teacher is evaluating. Pass out **H7 (Full 5E Learning Sequence for The Earth's Climate Constantly Changes)** so teachers can examine the entire 5E.

3. Display **S58 (Debrief some more)** ask participants to share their thinking on the question (whole group fine).

4. Display **S59 (Where were the 5E components)** Ask participants how this connection helped them think of the order of student thinking.

5. Display **S60 (Reflection)** Ask participants to do the output. If time, ask participants to share.

*Trainer Note. Reading **R13 (Constructivism and Conceptual Change part 1)** and **R14 (Constructivism and Conceptual Change part 2)** will help with fielding teacher questions/concerns over the lesson design. No instructional design will be perfect for all leaners, but this learning sequence was designed in a way to increase chances that students will gain conceptual understanding and provide them time to work with their prior knowledge.*