Thermodynamics in Earth's Systems

DEVELOPER: OpenSciEd

GRADE: HS | **DATE OF REVIEW:** May 2023

Educators Evaluating Quality Instructional Products

NextGen Science WestEd

Thermodynamics in Earth's Systems

EQuIP RUBRIC FOR SCIENCE EVALUATION

OVERALL RATING: E

TOTAL SCORE: 8

CATEGORY I: NGSS 3D Design Score	CATEGORY II: NGSS Instructional Supports Score	CATEGORY III: Monitoring NGSS Student Progress Score
2 (0, 1, 2, 3)	**3** (0, 1, 2, 3)	**3** (0, 1, 2, 3)

Click here to see the scoring guidelines.

This review was conducted by NextGenScience using the EQuIP Rubric for Science.

CATEGORY I CRITERIA RATINGS			CATEGORY II CRITERIA RATINGS			CATEGORY III CRITERIA RATINGS		
A.	Explaining Phenomena/ Designing Solutions	**Adequate**	**A.**	Relevance and Authenticity	**Extensive**	**A.**	Monitoring 3D Student Performances	**Extensive**
B.	Three Dimensions	**Adequate**	**B.**	Student Ideas	**Extensive**	**B.**	Formative	**Adequate**
C.	Integrating the Three Dimensions	**Adequate**	**C.**	Building Progressions	**Adequate**	**C.**	Scoring Guidance	**Adequate**
D.	Unit Coherence	**Inadequate**	**D.**	Scientific Accuracy	**Extensive**	**D.**	Unbiased Tasks/Items	**Extensive**
E.	Multiple Science Domains	**Adequate**	**E.**	Differentiated Instruction	**Adequate**	**E.**	Coherence Assessment System	**Extensive**
F.	Math and ELA	**Extensive**	**F.**	Teacher Support for Unit Coherence	**Adequate**	**F.**	Opportunity to Learn	**Adequate**
			G.	Scaffolded Differentiation Over Time	**Adequate**			

Summary Comments

Thank you for your commitment to students and their science education. NextGenScience is glad to partner with you in this continuous improvement process. The unit is strong in several areas, including connections to mathematics and opportunities for students to express ideas.

During revisions, the reviewers recommend paying close attention to the following areas:

- **Support for opportunities to learn.** For some learning goals, students are currently not given opportunities to repeatedly engage with the targeted elements. Providing students with repeated opportunities to develop and use all claimed elements from all three dimensions could help support students in developing proficiency.
- **Increasing structured feedback opportunities.** Building in prompted, structured feedback opportunities from both teachers and peers for all unit learning goals could help students receive feedback on their thinking and their progress toward the targeted learning goals.

Note that in the feedback below, black text is used for either neutral comments or evidence the criterion was met and purple text is used as evidence that doesn't support a claim that the criterion was met. The purple text in these review reports is written directly related to criteria and is meant to point out details that could be possible areas where there is room for improvement. Not all purple text lowers a score; much of it is too minor to affect the score. For example, even criteria rated as Extensive could have purple text that is meant to be helpful for continuous improvement processes; in these cases, the criterion WAS met; the purple text is simply not part of the argument for that Extensive rating.

Page numbers in this report under Criteria I.B, I.D, III.A, III.C, III.E, and III.F may reflect a more updated version of the unit than page numbers related to other criteria.

CATEGORY I

NGSS 3D DESIGN

I.A. EXPLAINING PHENOMENA/DESIGNING SOLUTIONS

Making sense of phenomena and/or designing solutions to a problem drive student learning.

i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving.

ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems.

iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.

Rating for Criterion I.A. Explaining Phenomena/Designing Solutions	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that learning is driven by students making sense of phenomena or designing solutions to a problem. The unit introduces an anchor phenomenon, and some of the lessons support students in making sense of it. Student questions and experiences are elicited and are used to drive or motivate most of the learning in the unit. However, not all of the learning in the unit is in service of sense-making, and the unit is organized in a way that may not always allow students to understand which phenomenon they are making connections to.

The Unit Overview states that "this unit is anchored by students exploring coastal communities that are affected by rising sea levels, which are forcing some communities to move" (page 1). The phenomenon of rising sea levels in several coastal communities is introduced to students in Lesson 1 and drives the learning for part, but not all, of the unit. Lessons 1–4 focus on understanding polar ice melt to explain sea level rise (which can connect back to the anchor phenomenon) and then Lessons 5–12 are partly driven by making sense of the phenomenon of a rapidly melting Greenland glacier and trying to understand the design of two proposed solutions for slowing the ice melt. Lessons 5–12 also focus on students learning many different topics (i.e., the correlation between carbon dioxide concentrations and global temperature changes, heat flow between hot and cold objects, feedback loops, heat required to melt ice, density, etc.), but it is not clear if students will always see the connection between these topics and the phenomenon of the rapidly melting glacier. Students also never come back explicitly to the coastal communities that are affected by rising sea levels, which results in the introduction of the coastal communities serving as a hook for the unit. The end of the unit discusses human-caused global climate change from which students could extrapolate some effect on the original towns, although they are not currently asked to make that connection. Related evidence includes:

- Lesson 1: Students watch three videos about three different locations in the world that have been affected by sea-level changes (page 35). This is intended to be the anchor phenomenon. Students record their observations and questions in their notebooks. After a class discussion the teacher says, "So the people in these communities are already being affected by sea level rise! If we know what is causing it, maybe we can understand how to stop it. The videos stated that there are some local reasons for why sea levels are rising. What are the local reasons for the Biloxi-Chitimacha-Choctaw community to have to move? What about coastal communities in Senegal or Sierra Leone?" (page 37). Follow ups to this phenomenon include:

  - Lesson 1: The *Community Responses to Sea Level Rise* handout shows students some ways different communities around the world are responding to sea-level rise (page 39).
  - Lesson 1: In Section 6, the teacher tells students, "we will draw models that explain why we think the sea level is rising" (page 43). Students are told "in chemistry, it is important that we try to figure out what is going on at the microscopic level, so our models should always talk about particles of matter or energy."
  - Lesson 2: In Section 10, students view a slide that states, "we established that melting polar ice is likely causing rising sea levels" (page 72). However, students do not really have an opportunity to explore any alternate explanations, and they were heavily guided to this explanation. Therefore, students are not truly engaged in sense-making related to this phenomenon.
  - Lesson 2: In Section 10, students are asked: "what does our evidence so far tell us about energy, matter, and climate?" (page 71). This focuses on the DCI content and topics instead of connecting to sense-making.
  - Lesson 4: In Section 13, the class manipulates a simulation that shows the effects of melting ice on sea level rise and on different coastlines (page 120). In Section 14, students discuss how humans could be affected by sea level rise (page 121). In Section 15, students brainstorm potential ideas that could stop or slow down polar ice melt (page 123). However, in the beginning of Lesson 5, the students participate in a class discussion about their "designs" when they never developed any designs, only ideas (page 131). By this point, most students may feel as if they have already completed explaining the intended anchor phenomenon, and therefore might not be engaged in sense-making.
  - Lesson 12: In Section 1, the teacher asks, "What have we been trying to figure out in this unit?" and the sample student response is "how can we slow the flow of energy on Earth to protect vulnerable coastal communities?" (page 267). However, this is not what was explicitly driving the learning for the unit past Lesson 4.

- Lesson 4: Students are asked to predict phenomena. Students think about what changes would happen to the oceans if Earth's cryosphere melted. The teacher is told to represent student ideas during an initial discussion of this question on chart paper in Section 2. Note that the section is titled "create initial model about melting ice" so it can be assumed it will be a model, but this is not explicit in the directions. At the end of the lesson in Section 13, the teacher displays the model developed and revises it based on student ideas (page 120).
- Lesson 5: Students are introduced to the phenomenon of a melting glacier in Greenland, and students spend most of Lessons 5–12 building an understanding of the design behind two proposed solutions to stop the melting glacier. Along the way, students learn all sorts of things that may or may not be related to the glacier from the student's perspective. The sequence ends

with students applying some of the knowledge learned along the way to explain the proposed solutions to the melting problem. Follow ups to this phenomenon/problem include:

  - Lesson 5: In Section 2, students observe photos and watch a video that depicts the melting of the Ilulissat Glacier (page 132). Students observe parts of the glacier break off (calving). Students are then given an image that shows the changing Ilulissat Glacier front location over the years. Students are asked "what changes do you notice?" and "what could be causing these changes?" (page 133). Although students build an understanding in the following lessons that warming temperatures can cause calving, students do not learn about other possible causes of calving and therefore are not able to fully explain the phenomenon.
  - Lesson 5: In Section 3, students are given two proposed design solutions that they will evaluate (page 133).
  - Lesson 5: In Section 7, students share their ideas about the initial models for the proposed solutions with the class to build an initial class consensus model (page 136). A margin note suggests to support collaboration by asking questions such as, "Is there anything about the phenomenon that we have not explained yet? Are there any gaps that need filling?" (page 136). However, students are not necessarily explaining a phenomenon, so this language could be confusing. They are instead illustrating how a proposed design solution to a problem (ice melt at Ilussiat Icefjord) will work.
  - Lesson 6: In Sections 7–8, students revise their models from Lesson 5 about how the microbead solution helps slow polar ice melt (pages 155–156). At the end of the lesson students reflect on whether microbeads make sense as a solution (page 161), and they continue this reflection as they build more understanding in Lesson 7.
  - Lesson 12: Students use a mathematical model to calculate the berm's impact on ice melt.
  - Although students learn about the microbeads solution and reflect on its potential use and then do the same for the berm solution, students never come back to explicitly comparing or evaluating the two designs compared to each other, which results in a large piece missing from their problem solving.

Student questions and thoughts related to the phenomena are elicited, revisited, and used to drive most of the sense-making in the unit. Some examples include:

- Lesson 1: In Section 11, students write down new questions that they have about the phenomenon (page 53). They share their questions with the class and the teacher develops a Driving Question Board (DQB). The teacher is instructed to, "Propose that these questions are all related to an overarching question, such as, "How can we slow the flow of energy on Earth to protect vulnerable coastal communities?" Title the DQB with this question or a similar one as phrased by your students" (page 54). Several of the sample student questions focus on ice melt and that ice melt is the cause of sea level rise. However, note that it is unlikely that students will pinpoint only this as the cause this early on. Students revisit the DQB in Lessons 3, 5, 7, and 13.
- Lesson 1: In Section 12, students generate ideas for investigations they could design to help them figure out the answers to their questions (page 54). An *Additional Guidance* box states

that the list of ideas can be revisited throughout the unit (page 55). The teacher is told to point out when a future lesson involves an investigation like the one the class has suggested. Student ideas for sense-making are explicitly elicited here and the teacher is told to revisit them, but reminders are not included to help ensure the teacher will revisit them in the actual lessons to help students feel as if their questions are driving the sense-making. At the end of the section the teacher states, "At this point we are unsure about the cause of sea level rise and if people have ever encountered something similar before, so that might be a good place to start" (page 54). However, Lesson 2, jumps immediately to ice melt as an explanation and other options are not really considered.

- Lesson 2: In Section 5, students are asked "what particular pieces of data might be interesting or helpful to see to answer our questions?" (page 69). After students share, the teacher says they will work on tracking down those data and then the next day, the teacher shares three pieces of data. Guidance for what to do if the sample student answers/selected data pieces are not the actual answers is not provided.
- Lesson 3: In Section 10, students share the questions they still have about the effects of carbon dioxide on Earth systems, and at the beginning of Section 11, the teacher is told to "use students' questions from the previous activity to introduce the reading" (page 96).
- Lesson 4: In Section 9, students are polled about the effects of sea ice compared to land ice (page 116). The teacher is then guided, "Then use the results of the poll to motivate the need to build evidence for our predictions. Say, Some of us think that sea ice has less of an effect than land ice because it is already in the ocean, while others are not sure. In Lesson 3, we did a good job of developing an investigation to produce evidence that we could use to support ideas like this."
- Lesson 5: In Sections 7–8, the teacher is told to keep track of student questions about the proposed solutions (pages 137–138). In Section 11, students share their questions with the class and the teacher is told to "lead students toward the idea of figuring out first how the microbeads work to prevent ice from melting and then returning to the berm later on" (page 142).
- Lesson 6: At the beginning of the lesson, students revisit which question(s) they were most interested in at the end of Lesson 5 (page 150). Students are asked "how can we test our specific ideas about how microbeads work?" and the teacher is told to listen to the following student responses ("we could try to see how hot different colors get under light" and "we could see how ice melts under different color objects") before saying "those are interesting ideas! Let's think more specifically about what this investigation could look like (page 150).
- Lesson 8: In Section 1, students develop questions about what is going on where the glacial ice meets the ocean water (page 177). In Section 4, students revisit the questions and answer the question "how might what we have learned help to answer the questions you had at the start of the lesson?"
- A diversity of student perspectives is rarely offered in the exemplar student questions. For example, the set of exemplar student questions does not include questions such as, "Why don't they (people in coastal towns) just move to where the ocean won't hurt them? Shouldn't the government build them better houses? Why can't they live on floating platforms like I've seen in

> PBS documentaries? Living close to the ocean is risky. Why should we be responsible for the risk those people took? Can't we just learn chemistry and not all this stuff about places I have no connection to?" If such student questions do show up, the materials do not offer guidance on how to handle them with the same attention to equity that is shown in the right-hand margin comments. It is possible that students who ask these types of questions figure out something different than the teacher intends (and directs the lesson towards), so these students would be less likely to experience student-driven sense-making.

Engineering is a partial learning focus, since some of the lessons ask students to try to understand and evaluate an engineering design solution to a problem. ETS elements are not specifically claimed as learning targets and the unit does not guide teachers to help students develop an understanding of engineering along with the PS and ESS DCIs. However, the engineering context is used to help students develop and use some science DCIs. The Unit Overview document on page 13 states that "The presented solutions provide a context for figuring out science ideas, but students are not intentionally engaged in defining problems or developing solutions, as engineering is systematically developed in OpenSciEd Unit C.4: Why are oysters dying, and how can we use chemistry to protect them? (Oysters Unit) and OpenSciEd Unit C.5: Energy from Chemical & Nuclear Reactions (Chemical Energy Unit)."

Suggestions for Improvement

- Consider making the coastal communities less of a "hook" for the unit. Explicitly making connections between this phenomenon and the multiple scenarios students are given could help the intended anchor phenomenon serve more as an anchor for the entire unit.
- Instead of having students use the Progress Tracker to track DCI understanding, consider helping them keep track of how their learning is helping them explain the phenomena.
- Consider modifying the instructional time for various activities such that students spend more time engaging in sense-making rather than simply learning about topics that may be related (but not directly connected) to the explanation for the phenomenon.

I.B. THREE DIMENSIONS

Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.

i. Provides opportunities to *develop and use* specific elements of the SEP(s).

ii. Provides opportunities to *develop and use* specific elements of the DCI(s).

iii. Provides opportunities to *develop and use* specific elements of the CCC(s).

Rating for Criterion I.B. Three Dimensions	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials give students opportunities to build understanding of grade-appropriate elements of the three dimensions. Although all of the claimed elements are at grade level and students have opportunities to develop or use most of the claimed DCIs, there is a mismatch between some of the claimed SEPs and CCCs and the evidence of their use or development by students.

Science and Engineering Practices (SEPs) | Rating: Adequate

The reviewers found adequate evidence that students have the opportunity to use or develop the SEPs in this unit because students have at least one opportunity to develop or use parts of most of the claimed elements in the unit. However, students do not have opportunities to fully develop or use many of the claimed elements.

Targeted SEP elements for each lesson are identified through text in the *Elements of NGSS Dimensions* pdf and through codes at the beginning of each lesson plan. Focal SEP elements for the unit are identified on pages 14–15 of the teacher guide. The language of some of these elements includes strikeouts, implying that those sections are not developed in the unit. However, the full list of the target SEP elements identified for each lesson through the *Elements of NGSS Dimensions* pdf and the codes at the beginning of each lesson plan do not have the strikeouts. Therefore, the portions of elements intended to be developed or used in the unit are unclear.

Asking Questions and Defining Problems

- *Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.*
    - Lesson 3: This element is claimed. In Section 3, students discuss what question they would like to answer in the investigation and then the class develops a consensus investigation question to seek additional information (page 86). Students ask a question after observing the phenomenon of Earth's increasing temperatures to seek additional information (to see what role carbon dioxide is playing).
- *Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.*

- Lesson 1: This element is claimed. In Section 7, when students share their initial models with partners, students record questions if questions come up during their conversations (page 45). Students possibly ask questions from examining models to seek additional information.
- Lesson 1: This element is claimed. In Section 11, students are prompted to "Look back at the questions you had in your Notice and Wonder chart, the questions you recorded during our modeling, and consider the related phenomena, too. Write down at least two new questions that you now have about the phenomenon we have been exploring" (page 53). Since this happens right after students discuss their initial consensus model of why sea levels are rising that focuses on microscopic particles, students most likely ask questions that arise from examining models to seek additional information. However, since the Notice and Wonder Chart refers to videos of coastal towns influenced by sea level changes, the cognitive and conceptual gap between coastal communities and microscopic particles is so large that it might be difficult for students to form meaningful clarifying questions or find ways to ask about additional information and relationships.
- Lesson 11: This element is claimed. In Section 2, the teacher is prompted to say, "We are trying to figure out how much matter is affected or melted when energy transfers from the water to the glacier. Based on what we have figured out, what would be a good question to investigate to complete our model?" (page 258). Note that students are already provided a general question by the teacher. Students use the *Investigation Question Development* handout to develop an investigation question. They consider what they already know about energy transfer between water and ice and what question could help them complete their model. However, note that there is no support for what "complete the model" means.

- *Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.*
  - Lesson 13: This element is claimed. In Section 4, students work with a partner to develop questions according to Slide G which states "to choose one of the questions from the *Modeling the Climate* handout" (page 284). Students are told to write the question in a way they can test with the model and to use the provided format (which is a sentence frame). Students are scaffolded to ask questions to determine relationships that can give somewhat quantitative answers, and they choose from a list of questions and are simply reframing the questions. Students therefore build toward this element.
- *Ask questions to clarify and refine a model, ~~an explanation,~~ or an engineering problem.*
  - Lesson 5: This element is claimed. In Section 3, the teacher uses the prompt, "What does not make sense?" to which students could potentially ask questions that clarify and refine the Greenland Glacier model proved to them in a handout. In Section 8, as the class discusses the consensus models for the proposed solutions in terms of energy, they are asked, "what questions do we need to ask to also model the energy transferring into, out of, and within the system?" (page 138). In response, students may ask questions to clarify a model.

- Lesson 7: This element is claimed. In Section 4, students add questions to the DQB (page 170). Students most likely ask questions to seek additional information.
- Lesson 7: This element is claimed. In the *Thawing Permafrost* Assessment, students are asked "what questions would you need to answer about this new idea to figure out how it affects the feedback loops in the permafrost thaw model?" The new idea is that thawing permafrost might lead to more carbon dioxide, a potential input to the permafrost feedback loop model. Students ask questions to clarify an explanation for a model.

- *Evaluate a question to determine if it is testable and relevant.*
  - Lesson 9: This element is claimed. In Section 3, students are given three questions and are asked "which of these questions would be the most testable and relevant to what we want to figure out? Why?" (page 199). The teacher guide then says to "Listen for these ideas (from students): Even though we care about (A), it is not really testable. (B) does not fully relate to or describe what we want to figure out. (C) is something we can test and it describes the specific question we want to clarify–why warm saltwater behaves differently than we expect based on its energy."
- *Ask questions that can be investigated within the scope of the ~~school laboratory, research facilities, or~~ field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.*
  - Lesson 8: This element is claimed. In Section 1, students develop questions about what is going on where the glacial ice meets the ocean water (page 177). Students are asked what information might help answer their questions and how might they figure this out if they were there. Students ask questions that could be investigated in the field; however, they do not know the available resources, so they do not engage with all parts of the element.
  - Lesson 8: This element is claimed. In Section 4, students generate hypotheses for two scenarios based on the energy model provided for them and what they have learned in the lesson (page 183), and therefore use the second part of the element.
- *Ask ~~and/or evaluate~~ questions that challenge the ~~premise(s) of an argument, the interpretation of a data set, or the~~ suitability of a design.*
  - Lesson 5: This element is claimed. In Section 3, a model of how to slow the melting of a Greenland Glacier is provided to students along with a proposal to spread microbeads (essentially sand) on the glacier (page 133). Then the teacher says, "We might have initial ideas about whether or not these solutions would work, but let's take some time to consider these decisions. Just because a solution might work, does that mean we should do it? Who or what might be affected?" These prompts may result in students asking questions that challenge the suitability of a design. In Section 7, as the class builds a consensus model for the proposed solutions, students are asked "what does not make sense about the proposed solution?" (page 138). In response, students might ask questions that challenge the suitability of a design.

Developing and Using Models

- *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
    - Lesson 1: This element is claimed. In Section 6, students develop an initial model to "explain why they think the sea level is rising, including what they think is happening at a scale too small to see" (page 43). Question 3 in the *Initial Model* handout prompts students to include "different components (parts), including ocean water; lines, arrows, or other symbols to show relationships between different components; a key that shows what any colors or symbols mean." Students develop a model to illustrate relationships between components of a system; however, the idea of systems is not made explicit. At this point, students do not use evidence in their model. Question 4 in the *Initial Model* handout prompts students to "draw a model to show what you think is happening at the particle level to cause the sea level to rise. Make sure your model shows any changes or flows of matter (particles) and energy." Students develop a model that will likely illustrate relationships between components of a system; however, the idea of systems is not made explicit. At this point, students do not use evidence in their model.
    - Lesson 3: This element is claimed. In Section 9, students work as a class to develop a model of energy flow in their investigation system (page 93). Students are asked questions about the energy flow and are asked "what evidence do we have for that?" (page 94). Students work as a class to develop a model based on evidence to illustrate the relationships between components of their investigation system in terms of energy.
    - Lesson 6: This element is not claimed, but in Section 7, students revise their models from Lesson 5 about how the microbead solution helps slow polar ice melt (pages 155). Students revise a model based on evidence from the investigation and reading to illustrate the relationships between components of a system. In Section 9, students use the model to make a prediction about what might happen to polar ice in the future (page 157).
- *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.*
    - Lesson 12: This element is claimed. In Section 3, students use the *Berm Model* handout to develop a model that answers the question, "How much does the berm solution impact energy flows and sea level?" (page 269). Students also develop a mathematical model in the *Calculating Berm Impact* handout. Although students develop models, there is no explicit discussion of mechanistic accounts, flexibility, merits, or limitations, so students do not develop the entire element.

Planning and Carrying Out Investigations

- *Plan an investigation ~~or test a design individually and~~ collaboratively to produce data to serve as the basis for evidence as part of ~~building and~~ revising models, ~~supporting explanations for phenomena, or testing solutions to problems~~. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.*

- Lesson 3: This element is claimed. In Section 3, students develop a consensus investigation question (page 86). The teacher provides students with the *CO2 Investigation Procedure* handout, which has the procedure students will conduct for the investigation. Students are told to read through the procedure and identify "what will change, what will be measured, and what will be kept the same in the investigation." Students do not plan an investigation since the investigation has already been planned for them. In Section 6, students discuss as a class how often they will take measurements (page 90). Students only collaboratively conduct an investigation.
- Lesson 4: This element is claimed. In Section 10, the class develops an investigation question about the effects of melting sea ice (page 117). The teacher tells students what materials they have available for the investigation, and the class discusses what each material can be used for. Students work in groups to build a data table for the investigation in their notebook, during which they are asked to consider how to represent the independent and dependent variables. The teacher discusses the importance of recording procedures and sketching diagrams of lab setups and adds this to the investigations anchor chart (page 118). While students are asked to "measure and sketch diagrams of each system in their notebooks" and the guide states that "*Sample Investigation Procedure* describes an example procedure," there are no explicit directions that ask students to develop a procedure for the investigation. Lesson Slides Y and Z tell students what to do for most of the investigative procedure. Students also only collaboratively conduct an investigation.
- Lesson 6: The last sentence of this element is identified as a targeted element. In Section 2, students are given the investigation design for the light investigation, and they use the investigation anchor chart from Lesson 3 to identify the variables "that need to be considered, changed, and controlled" and "how do we make sure these variables are controlled?" (pages 148–149). Through these questions, students consider the second piece of the element, ensuring variables are controlled The teacher is told to ask students "Do we always remember to control all the variables we should? Students will likely say no. Point out that if a variable should be controlled but is not, and the data are affected, we call that a confounding variable. It "confounds" because it messes up both the independent and dependent variables in a way that is unpredictable" (page 151).

- *Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, ~~risk,~~ time), ~~and refine the design accordingly~~.*
  - Lesson 10: This element is claimed. In Section 2, students discuss and decide on the investigation question as a class (page 227). The teacher provides students with the materials they will have for the investigation and the class discusses how each piece can be used. The class discusses the benefits vs. drawbacks of carrying out one trial for many conditions or many trials for fewer conditions. In Section 3, students work first independently and then collaboratively in groups to outline their procedures for three

different testing conditions and to create the data tables they will need. A class data table is provided to students in an Excel spreadsheet format. This data table implies (does not explicitly state) that the number of trials is equivalent to the number of groups. Individual teams do not appear to repeat trials, which is the traditional way reliability is determined. Slide H discusses safety, which might be the way risk is broached in this element. On page 235, instructions say, "Suggest that we try this with more data." This teacher prompt could refer to multiple trials, but it is not clear. The words precision and accuracy are not used explicitly, and the concept of limitation is not linked to precision or accuracy. There is no explicit discussion of cost or time. In Section 16, students work collaboratively as a whole class to identify the question, variables, and data for an investigation plan (pages 243–244). The class discusses how they will organize the collected data and how they will identify/record a quantitative change in the temperature. Students do not discuss how much data, the accuracy of data, or limitations on the precision of the data.

- *Plan and conduct an investigation or test a design solution in a safe ~~and ethical~~ manner including considerations of ~~environmental, social, and~~ personal impacts.*
    - Lesson 6: This element is claimed, and the Elements of NGSS Dimensions says that students consider how they can carry out the investigation to ensure personal safety. Students conduct an experiment (see evidence for SEP element 3.2), and discuss how to do so safely.
- *Select appropriate tools to collect, ~~record, analyze, and evaluate~~ data.*
    - Lesson 9: This element is claimed. In Section 3, students discuss what sorts of data they can collect to figure out an answer to their question, how they can organize their data table, which tools would be most useful to measure mass and volume, and why the tools would be particularly useful (pages 199–200). The teacher is prompted to display Slide G and say, "If we want to measure temperature, that is pretty easy. But what tools here would work best to measure other variables?" Slide G shows a photo of a few pieces of lab equipment that students select from. Students are supported to begin building an understanding of selecting appropriate tools to collect and record data.
- *Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.*
    - Lesson 3: This element is claimed. In Section 5, students use the sentence stem provided to complete creating a hypothesis for the carbon dioxide investigation (page 88). The sentence stem is "if the amount of carbon dioxide in the system increases, then the temperature of the system will…." Students are heavily scaffolded in making a directional hypothesis.
    - Lesson 9: This element is not claimed. On page 202, the teacher asks "What do we think would happen to the mass of the water in the container if we had twice the volume that we have now? What if there were four times as much water? Or eight times as much water?"
    - Lesson 11: This element is claimed. In Section 3, students finish the directional hypothesis statement in the *Water-Ice Investigation Procedure* handout (page 259).

Students are provided with the sentence stem "When heat from the warm water increases, the mass of the ice that melts will…" to complete the hypothesis. Students are heavily scaffolded in making a directional hypothesis.

Analyzing and Interpreting Data

- *Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.*
  - This element is part of a targeted PE for the unit, but this element is not claimed as a learning target for any of the lessons. There is no explicit discussion in the unit about valid and reliable claims or optimal solutions, so although students may use tools or models to analyze data in the unit, they do not have opportunities to engage with the entire element. For example, in Lesson 9 Section 5, students use Google Sheets to create scatter plots from their data, to create a line of best fit for each scatter plot, and to calculate the mean (pages 204–207). Students use computer tools to help analyze data, but they do not use it to determine an optimal design solution or to make valid and reliable scientific claims.
- *Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.*
  - Lesson 9: This element is claimed. In Section 5, students use Google Sheets to create scatter plots from their data, to create a line of best fit for each scatter plot, and to calculate the mean (pages 204–207). Students then individually answer the questions about what the slopes mean in context of what they were measuring, what the slopes tell them, and which lines have steeper slopes.
- *Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.*
  - Lesson 9: This element is claimed. In Section 6, after students discuss the graphs of their data, the teacher reminds them that the mathematical models they produced might have sources of error and asks students, "What are some limitations in the mathematical models the computer produced?" (pages 205–206). The limitations of the mathematical model used by the computer are not the sort of limitation referred to in this element, which refers to error sources due to measurement and processes. It is highly unlikely that the computer program introduces the same kind of uncertainty to the results.
- *Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.*
  - Lesson 2: This element is claimed. In Section 2, students analyze the graph in the *Sea Level and Related Data* handout (pages 65–66). Students discuss what patterns they notice in the data and what relationships might exist between temperature, sea level, and ice volume. In Section 4, students are assigned readings and then they are asked "what did you figure out from the readings?" and "how could the data in the readings help us to answer our questions?" (page 68). In this last question, students could discuss

the impact of new data on their explanation. However, there is no explicit reference to an evaluation, a working explanation, or a model of a proposed process or system, though such references could be made by experienced teachers.

Using Mathematics and Computational Thinking

- *Create ~~and/or revise~~ a computational model or simulation of a ~~phenomenon, designed device, process, or~~ system.*
    - Lesson 12: This element is claimed. In Sections 3–5, students develop and use mathematical models. However, there is no explicit evidence of students creating computational models or simulations.
- *Use mathematical, computational, ~~and/or algorithmic~~ representations of phenomena or design solutions to ~~describe and/or~~ support claims ~~and/or explanations~~.*
    - Lesson 6: This element is claimed. In Section 11, students calculate the cost of using microbeads as a solution to protect the Ilulissat Glacier and then make a claim about the question "are microbeads actually 'worth it' as a solution to protect Ilulissat Glacier?" (page 160). Students use mathematics to support a claim about a design solution.
    - Lesson 12: This element is claimed. In Section 3, students use the *Berm Model* handout to develop a model that answers the question, "How much does the berm solution impact energy flows and sea level?" (page 269). Students use mathematical representations of energy affecting matter (ice melt) to support their model development. In Section 5, the *Calculating Berm Impact* handout leads students through the calculation required to determine if the berm solution works. At the end of this guided worksheet, students are given the following prompt: "Make an evidence-based claim: Would the design solution you have been evaluating to block the flow of warm water into the ice fjord stop enough energy transfer to prevent all of the melt occurring at Ilulissat Glacier, or only some of it? Explain how each of the following support your claim: your calculations, energy conservation." Students use mathematical representations and calculations of design solutions to support claims.
    - Lesson 13: In Sections 3–7, students use a computational model and test questions that can be answered by the computational model (pages 283–285). The *Assessment Opportunity* box states that "students should make claims that are supported by the use of the computational model," and the teacher is told to "Accept all responses that support claims using the model, tie back to matter and energy flows, and support the idea that the effects of climate change will continue if humans do not make changes in behavior" (page 285). However, note that the teacher is not supported to know what successful student responses would look like.
- *Apply techniques of algebra and functions to represent ~~and solve~~ scientific ~~and engineering~~ problems.*
    - Lesson 10: This element is claimed. In Section 8, during the class discussion about the calculated areas on the graphs, students build an understanding that energy was conserved as it was transferred in a closed system (page 236). The teacher writes down key idea #3 on the chart paper $ma \cdot \Delta Ta - mb \cdot \Delta Tb = 0$ (page 237). Students copy the

equation and write down its meaning (energy is conserved, it is not created or destroyed). In Section 18, students analyze the graphs and discuss the best-fit lines (page 246). The teacher then introduces the idea of specific heat and adds the equation for specific heat to a chart paper (page 247). The teacher helps students connect their mathematical work back to different temperatures of ocean water interacting with glaciers.

- *Use simple limit cases to test ~~mathematical expressions, computer programs, algorithms~~, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.*
    - Lesson 10: This element is claimed. In Sections 9–10, the teacher introduces a particle motion simulation that is used to understand heat transfer between two solids via conduction. The teacher is prompted to ask, "What happens if the two substances have very different temperatures?" The teacher guidance in the related A*ssessment Opportunity* box states that this prompt is limit case. Later on, page 239, a teacher prompt says, "Did your observations make sense with what you see in the world?" This could be an example trying to make sense based on what is known in the real world. A teacher sidebar note also says "Using extreme situations to test if a model "makes sense" in that range is called a limit case. Highlight to students that by comparing the simulation's behavior to what we know about a hot and cold substance in contact in the "real world," we can ensure that the model is reflecting actual behavior under the conditions that we care about" (page 239).
- *Apply ratios, ~~rates, percentages,~~ and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).*
    - Lesson 4: This element is claimed. In Section 6, students convert from meters to kilometers when calculating the volume of ice in Greenland and Antarctica (page 112). Students complete simple unit conversions for these calculations. In Section 7, during a class discussion about mathematical strategies and tools, the teacher reviews how to calculate unit conversions (page 114). The *Sea Level Calculations* worksheet requires students to use and make sense of ratios, percentages, and unit conversions.
    - Lesson 12: This element is claimed. In Section 5, students complete the *Calculating Berm Impact* handout (page 272). The calculations on the handout use ratios and rates in service of determining if the berm idea will decrease glacial melting enough to be worth it. The calculations use compound units. Since the handout is a set of guided questions and tasks, it supports students gaining competency on this element.

Engaging in Arguments from Evidence

- *Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.*
    - Lesson 2: This element is claimed. In Section 11, students work in groups to construct an argument (page 72). The *Data Analysis* handout provides an organizational chart for students to record information about the potential different causes they have looked at

for recent temperature change. Students are then given the prompts "I think _____ is the most likely cause of current temperature increases/polar ice melt/sea level rise, because the data show…." and "Explain how changes you saw in the data tell you the most likely cause." In completing this handout, students construct a written argument based on data and evidence.

Obtaining, Evaluating, and Communicating Information

- *Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.*
    - Lesson 8: This element is claimed. In Section 2, students watch a video about how the Inuit build indigenous knowledge about changing conditions (page 180). In Section 3, students read a text with visuals to gather scientific information about where NASA scientists think the glacier's melting is coming from (pages 181–182). Students are gathering scientific information from different sources, however students do not assess the evidence and usefulness of each source, so students engage with this element at a lower grade-band level.

Disciplinary Core Ideas (DCIs) | **Rating: Adequate**

The reviewers found adequate evidence that students have the opportunity to use or develop the DCIs in this unit because students have at least one opportunity to develop or use part of each claimed element in the unit. However, students do not have opportunities to fully develop or use some of the claimed elements.

DCI elements are claimed as learning targets for each lesson through codes in the "What Students Will Do" and through text in the "Where We Are Going" sections at the beginning of each lesson. The Assessment sections and What Students Will Do sections often refer to a targeted DCI element through color coding objectives and including the DCI code. For example, In Lesson 1, the claimed DCI is "ESS3.B.1," and the presumed full element is "Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations." However, the color-coded language that has parsed references to possible claimed elements only refers to the claimed DCI by the phrase, "resulting impact on human migration." Soon after this incomplete statement of the claimed DCI comes an alternative incomplete phrasing, "changes in human migration." The fact that these two parsings are substantively different could be confusing to teachers and decrease their ability to support students in learning this targeted learning outcome. Moreover, neither incomplete phrasing of the claimed DCI is the same as the actual full DCI element. The materials do not support teachers to link the incomplete parsing of DCI elements to the full element statement.

ESS3.B Natural Hazards

- *Natural hazards ~~and other geologic events~~ have shaped the course of human history; ~~[they]~~ have significantly ~~altered the sizes of human populations and have~~ driven human migrations.*

- Lesson 1: Parts of the element are claimed (*Natural hazards ~~and other geologic events have shaped the course of human history; [they]~~ have significantly ~~altered the sizes of human populations and have~~ driven human migrations*). Students watch a video in which they see how hurricanes have driven human migrations. Students begin to build an understanding toward the portion of the element that is claimed.
- Lesson 4: Parts of the element are claimed (*Natural hazards and ~~other geologic events~~ have shaped the course of human history; [they] have ~~significantly altered the sizes of human populations and have~~ driven human migrations*). In Section 14, the lesson helps students consider the human impacts of sea level rise (page 121). Students calculate how many people in the US may be affected by a 0.5 meter sea level rise. However, students do not explicitly consider how natural hazards have shaped the course of human history.

ESS1.B Earth and the Solar System

- *Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.*
  - Lesson 2: This element is claimed. In the *Earth's Orbit and Light Energy from the Sun* reading, students learn the basics about the Milankovitch cycles and the three different ways in which long-term changes in the orbit might affect climate and seasons (page 69). Students read about how the Earth's tilt does not change during the year, but the part of the Earth that is tilted toward the Sun changes and its elliptical orbit and how those contribute to seasons. Students read that "these small changes in seasons can slowly add up over hundreds or thousands of years to result in changes in climate." Note that it may be difficult for students to grasp exactly how the small changes in seasons can result in changes to the climate.

ESS2.A Earth Materials and System

- *Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.*
  - Lesson 6: This element is claimed with the exception of the word "or decrease." In Section 9, when students use their model to discuss what might happen to polar ice in the future, students discuss energy flows and the teacher introduces feedback loops and states that a feedback loop is "when one change in a system causes other changes in the system that affect the original change" (page 158). Students are asked how the microbeads can lessen the damage caused by that feedback loop. The teacher prompts potentially address the idea that Earth's system are dynamic and respond to input changes. The changes to be considered by students here varies from carbon dioxide concentration changes to microbead use (or not).
  - Lesson 7: This element is claimed. In Section 1, students discuss what Earth systems or parts of the natural world could be involved in feedback loops (page 167). In Section 2,

students look at an infographic that shows examples of positive and negative feedback loops in Earth systems (page 168). Students participate in a class discussion in which they learn the difference between positive and negative feedback. It is implied that feedback loops are dynamic since the nature of feedback is some sort of movement or change.

- *The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.*
    - Lesson 2: This element is claimed. In the *Year Without a Summer* reading, students read about how solar irradiance changes on an 11-year cycle and that changes in climate can occur relatively rapidly because of a decrease in light reaching Earth (page 69). Students access information in the lesson that allows them to complete *a Data Analysis* handout. The handout analysis deals with orbital cycles, volcanic activity, solar activity, and atmospheric carbon dioxide concentrations. In the handout, energy input changes, glaciers, and different time scales are mentioned, thus providing students with the opportunity to address most of the element.
    - Lesson 8: This element is claimed with the exception of: "or Earth's orbit, tectonic events," "circulation, volcanic activity," and "vegetation." In Section 3, the teacher is told to "Say, It sounds like changes are happening on a very short timescale in this region" (page 183). Then through the *NASA OMG Project* handout and video, students learn how water circulation is contributing to glacier melt in Greenland. In Section 4, students use some of the understanding to complete the *Revisiting Questions and Revising Models* handout. Students build toward a tiny piece of this element. The video does not mention geological record.

ESS2.D Weather and Climate

- *The foundation for Earth's global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.*
    - Lesson 3: This element is claimed with the exception of "electromagnetic, "reflection," and "energy's re-radiation into space." In Section 9, after the class creates an energy model for the investigation system, the teacher asks students how the energy transfer model would be different if they applied it to the Earth (page 94). The expected student responses are "energy comes from the Sun, not a heat lamp; there is nothing holding Earth's atmosphere 'in' like a bottle;" and "the higher-temperature atmosphere would cause polar ice melt." Although students understand that energy comes from the sun and affects the atmosphere, they do not explicitly build an understanding of this element.
    - Lesson 6: This element is claimed with the exception of "electromagnetic." In the *Light and Materials* reading, students learn that light can be reflected, absorbed, or

transmitted through material. Students learn that "carbon dioxide and other greenhouse gases transmit (or let through) visible light but absorb infrared light, meaning the energy is soaked up by the gas molecule. In contrast, the other gases in Earth's atmosphere transmit both visible and infrared light, so they let infrared light coming off Earth's surface escape into space." Students also read that some energy is reradiated as infrared light. Page 159 asks students to update their glossaries and progress tracker in reference to the reason why spreading glass beads on a glacier slows the rate of melting. One suggested answer says, "Glass beads have high albedo (reflectivity), so some of the energy is not absorbed by the ice underneath." This is partial fulfillment of this element. Students develop pieces of the element, but note that it may be difficult for them to put the understanding all together. The idea of foundations of global climate systems, storage, and redistribution are not mentioned explicitly.

  - Lesson 9: This element is partially claimed (*The foundation for Earth's global climate systems is the ~~electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and~~ redistribution among the ~~atmosphere~~, ocean, ~~and land systems, and this energy's re-radiation into space.~~*). In Section 2, students discuss as a class how the ocean gets energy from the Sun and from warm air (pages 196–197). The teacher is told to ask "We now know that the ocean is transferring energy. Where does that energy come from, and how might it affect the Earth's climate as it transfers throughout the ocean or to other systems?" (page 219). Students might therefore build toward this DCI.

- *Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.*
  - Lesson 2: This element is claimed. In the *Earth's Atmosphere* reading, students learn that Earth's atmosphere has changed over time, that the carbon dioxide originally in the atmosphere came from volcanoes, and that very little oxygen gas was present in the atmosphere until cyanobacteria appeared and converted the carbon dioxide to oxygen (pate 69). Students begin to build the idea that some organisms contributed to Earth's changing atmosphere.
  - Lesson 7: This element is claimed. In Section 2, students look at an infographic that shows examples of positive and negative feedback loops in Earth systems (page 168). One of the examples titled *long-term evolution of the atmosphere* has a feedback loop start with plants and photosynthetic organisms evolving, then growing, and then atmospheric CO_2 decreasing as it is used in photosynthesis. The large-scale timeline below these examples implies (does not explicitly state) the gradual nature of changes due to plants and other organisms. Through this diagram, students may pick up the idea that gradual atmospheric changes happened due to plants using photosynthesis, but it is not a focus.
  - Lesson 13: This element is claimed. In Section 2, the *Modeling the Climate* reading states that "plants and oceans both absorb carbon dioxide from the atmosphere" (page 281). The reading also states that "if people continue emitting lots of carbon dioxide that

stays in the atmosphere, global temperatures, polar ice melt, and sea level rise are all very likely to increase," so students may link the two topics.

- *Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.*
    - Lesson 3: This element is claimed. The *Atmospheric Carbon Dioxide* reading states that "Carbon dioxide is a particularly important greenhouse gas because it is being released at a high rate as we burn fuels like gasoline and coal." This introduces the idea that human activity contributes to increased carbon dioxide. On page 94, the teacher is instructed to ask, "How would the energy transfer model be different (change) if we wanted to show how atmospheric CO_2 affects ice melt on Earth?" Here, students show how carbon dioxide can affect the climate, and are asked where the CO_2 comes from (page 97).
    - Lesson 13: This element is not claimed. In Section 2, in the *Modeling the Climate* reading states that "if people continue emitting lots of carbon dioxide that stays in the atmosphere, global temperatures, polar ice melt, and sea level rise are all very likely to increase" (page 281).
- *Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.*
    - Lesson 3: This element is partially claimed with the exception of *"and by the ways in which these gases are absorbed by the ocean and biosphere*." The *Atmospheric Carbon Dioxide* reading states that "If we did stop releasing carbon dioxide into the atmosphere tomorrow, global temperatures would still end up about 0.5°C (0.9°F) higher in 2100 than they were in 2000. More realistic scenarios in which humans do continue to release carbon dioxide result in predictions of warming of between 1.2°C (2.2°F) and 4°C (7.2°F). This is a wide range in part because scientists are uncertain which path countries, companies, and people will take. Any scenario would result in significant continued sea level rise, but these predictions are helpful because they give scientists, activists, and policymakers the tools to identify possible solutions." The reading mentions the future, hints to human-generated greenhouse gases, and tells students that the temperature will increase. However, there is no mention of regional climate change.
    - Lesson 13: This element is claimed. In Section 2, in the *Modeling the Climate* reading, students read about the fact that there are differences between climate models, but that all models agree "that if humans do nothing to change their behavior, the climate will keep warming. If people continue emitting lots of carbon dioxide that stays in the atmosphere, global temperatures, polar ice melt, and sea level rise are all very likely to increase…" (page 281). The *Heat Pump* handout scenario states, "If heat pumps are widely adopted, they could eventually make a major dent in global carbon emissions by reducing direct emissions from indoor furnaces. As electric grids shift from fossil fuel power plants to renewables, more heat pumps could mean slashed emissions from both

heating and cooling. Installing an electric heat pump can be expensive up front, but in the United States, new legislation is making it easier for consumers to make the switch. But electric heat pumps are not totally free of issues."

ESS2.E Biogeology

- *The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.*
  - Lesson 7: This element is claimed. In Section 2, students look at an infographic that shows examples of positive and negative feedback loops in Earth systems (page 168). In the long-term evolution example, the handout states that over time, organisms evolve to take advantage of increases in carbon dioxide. This example helps students begin to build an understanding of this element.

ESS3.A: Natural Resources

- *Resource availability has guided ~~the development of~~ human society.*
  - Lesson 12: This element is claimed. In Section 8, students complete an Exit Ticket that gives them some information about electrical cars and states how mineral supply constraints are looming and that "some of the materials that are used to make them will be harder to find" (page 275). This introduces the idea behind this element.

ESS3.D Global Climate Change

- *Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.*
  - Lesson 4: This element is claimed. Students calculate the number of humans potentially affected by sea level changes (page 121). However, there is no explicit mention of the human impacts being greater than ever and no mention of increased modeling or management abilities.
  - Lesson 5: This element is claimed. The lesson focuses on two potential ways to slow the melt rate of a big glacier in Greenland. Mostly, students work through the relative merits of these two solutions both from a science concept (page 134) and human impact perspective (page 135). There is no clear reference to human impacts being greater than they have ever been nor to our increased ability to model future impacts.
  - Lesson 12: This element is claimed. An *Assessment Opportunity* box states that "Students should create a checklist that could be used to build a computational model that uses ideas from the unit to predict human impacts on the Earth system," and teacher instructions state, "Display slide I. On chart paper, add the Gotta-Have-It Checklist items that would be useful to include in a computational model that answers the question, What are the intended and unintended impacts of human activity on polar ice melt and sea level rise?" (page 275). Students may build understanding of modeling and predicting future impacts.

    - Lesson 13: In Section 2, in the *Modeling the Climate* reading, students read about the impacts of increased amounts of carbon dioxide (from human activity) will have. The reading also walks students through how scientific climate models work (page 281).
- *Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.*
    - Lesson 4: This element is partially claimed, with the exception of "and the biosphere." In Section 13, the teacher says, "Our model is an important tool because it can help us think about how sea level rise is actually occurring. However, this simulation does a really good job of reminding us that this is a problem that affects real places and real people" (page 120). Students implicitly build an understanding of part of this element. There are no important discoveries highlighted by the lesson flow, and the focus of the debriefing of the simulation is how students feel, not interactions and modifications in response to human activities.
    - Lesson 13: This element is claimed. Students read about climate models in *Modeling the Climate* and learn about how climate models work and that scientists use the differences between the model output and the data to refine equations/assumptions and improve models. Students read how models are helping scientists understand the climate. The reading states "There are two reasons a scientist might be uncertain about what equation to use: 1. Scientists are still figuring out what the relationship is or are trying to understand an interaction they recently discovered" (pages 1–2).

PS3.A Definitions of Energy

- *Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another ~~and between its various possible forms~~.*
    - Lesson 10: This element is partially claimed: *Energy is a quantitative property of a system that depends on the motion and ~~interactions of matter and radiation within that system.~~ That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another ~~and between its various possible forms.~~*
        - On page 236, the teacher's rhetorical prompt says, "This sounds like energy stays the same or is conserved. Is that right?" This prompt is in the context of a liquid-liquid heat transfer investigation. Later, on page 237, the teacher prompt says, "How could we know for sure that energy is conserved?" The exemplar student answer says, "We would have to measure it." Measurement implies that energy is a quantity, although this is not explicit for students. On page 238, the teacher says, "What happens when two substances of different temperatures touch each other?" The student response implies energy transfer from hot to cold. Students begin to build an understanding of parts of the

element, but the idea of a quantitative property is not made explicit for all students.

- In Section 8, the teacher guides a class discussion about the areas that students graphed to help students come to the conclusion that energy was conserved in their investigation, that the same amount of energy that flowed from the warm water went to the cool water (pages 237-238). The *Assessment Overview* box says that, "students should state that energy transfers between the warm and cool water, the areas of the graphs resemble quantities of energy, and energy is conserved" (page 238). .

- Lesson 12: This element is partially claimed: *Energy is a quantitative property of a system that depends on the motion ~~and interactions of matter and radiation within that system~~. ~~That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as,~~ within the system, energy is continually transferred from one object to another ~~and between its various possible forms.~~* The guided questioning worksheet *Calculating Berm Impact* provides students opportunities to view energy as a quantitative property (calorie calculations). The worksheet frames these energy calculations in the context of energy transfers among sunlight, warm water, and ice.

PS3.B Conservation of Energy and Energy Transfer

- *Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.*
  - Lesson 11: This element is claimed. In Section 3, a teacher prompt says, "Why can we graph the heat transfer from the water with the mass of ice melted? Shouldn't we graph the heat transfer to the ice instead?" (page 259). The sample student answer says, "They should be the same amount of heat because energy is conserved."
- *Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.*
  - Lesson 3: This element is claimed. In Section 9, students work as a class to develop an energy model (page 93). Students are asked, "did the energy ever disappear?" (page 94). The sample student responses are, "The bottles kept getting hotter as more energy was added to them, so probably not. It might leave the bottle, but we do not have evidence that it ever disappeared." The teacher then says "We have an interesting idea on the table that the energy does not disappear. Is there a way we could modify our model to show that the energy that went in is the same as the amount of energy at the end?" Through these questions, students begin to build a basic understanding of the idea of the first part of this element.
  - Lesson 5: This element is claimed. In Section 4, when students develop an initial model to explain what they think is happening at the particle level to make their assigned solution work, they may engage with the idea that energy can be transported from one place to another and transferred (page 134). The use is not explicitly scaffolded so all students may not engage with that piece of the element. In Section 8, the teacher

provides a sketch that shows how energy transfers from sunlight to ocean water to a glacier (page 139). This gives students an opportunity to think that energy is transported from one place to another in a system. However, there are no explicit references to energy not being able to be created or destroyed in contrast to energy being transported.
- Lesson 13: This element is claimed. In the Heat Pump Transfer Task rubric, there is reference to energy conservation. For example: "Students give responses which state or imply that energy is created or destroyed."

- *Mathematical expressions, which quantify how the stored energy in a system depends on ~~its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and~~ speed, allow the concept of conservation of energy to be used to predict and describe system behavior.*
  - Lesson 10: This element is claimed. In Section 8, the teacher guides a class discussion to help students come to the conclusion that energy was conserved in their investigation, that the same amount of energy that flowed from the warm water went to the cool water (page 236). The teacher shows that this idea can be represented by a mathematical equation (page 237). In the *Summarizing of Investigation* handout, students see and use the equation for heat, $m_A \cdot \Delta T_A$ = heat, which quantifies heat. In the simulation investigation, students associate particle motion with energy (page 242). Since conservation of energy was developed in the liquid-liquid heat transfer lab, it could be used to predict what happens in the simulation. That prediction is that the two materials in contact with each other will eventually reach the same temperature.
- *Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., ~~water flows downhill,~~ objects hotter than their surrounding environment cool down).*
  - Lesson 10: This element is claimed.
    - In Section 5, students participate in a building understandings discussion in which they discuss how energy transfer between two samples initially at different temperatures results in the same final temperature (page 230).
    - In Section 8, students are expected to respond with the understanding that energy goes from warm water to cool water when they have a class discussion about their investigation (page 236).
    - In Section 11, the teacher asks several leading questions regarding a particle motion simulation that depicts energy transfer from hot to cold solids (page 239). One prompt says, "What did the particles have to do to prompt you to click "stop"?" The sample student answer is, "The energy was spread throughout both objects, instead of mainly in one." Through these prompts, students probably begin to build an understanding of uniform energy distribution. A teacher sidebar note says "If it is unclear from student responses, follow up by asking, If the temperature is the same, how is the energy spread or distributed? Use the simulation to show that it is spread evenly. Use examples

like cooling coffee and refrigerators to highlight that this spread happens in uncontrolled systems, but not in controlled systems (page 240).

- Lesson 13: This element is claimed. In the Heat Pumps Assessment Task, students are asked "What is happening at the particle level that explains why allowing warm air into one part of the room from the heat pump system causes the whole room to heat up? Use both matter and energy in your response" (page 9). The scoring guidance asks teachers to look for student responses that include the idea that "the process continuing until energy is evenly distributed and temperature is consistent throughout the room" (Heat Pumps Rubric page 10).

PS3.D Energy in Chemical Processes

- *Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.*
    - Lesson 6: This element is partially claimed, with the exception of "thermal." In a discussion about energy flow in Section 9, students are asked "why doesn't the energy just disappear?" one of the sample student responses is "energy is conserved – it cannot be destroyed or disappear. It has to go somewhere" (page 158). While this shows basic student understanding of the idea that energy cannot be destroyed, the lesson does not explicitly discuss how energy can be converted to less useful forms.
    - Lesson 13: This element is claimed. In the transfer task, students are asked "Might there be other places where energy comes into the system or where energy exits the system that are not marked with arrows in the diagram? If so, add those places to the diagram and explain how this would affect the usefulness of the system." In the scoring guidance, the teacher is told that one of the key elements in the student response is to "Indicate that energy outside the system is not useful" (Heat Pumps Rubric, page 3).

Crosscutting Concepts (CCCs) | **Rating: Adequate**

The reviewers found adequate evidence that students have the opportunity to use or develop the CCCs in this unit. Although CCC elements are claimed at a grade-appropriate level for each lesson, students do not have opportunities to develop or use the full elements in some of the claimed instances.

Targeted CCC elements for each lesson are identified through text in the *Elements of NGSS Dimensions* pdf and through codes at the beginning of each lesson plan. Focal CCC elements for the unit are identified on pages 14–15 of the Teacher Guide. The language of some of these elements includes strikeouts, implying that those sections are not developed in the unit. However, the full list of the target CCC elements identified for each lesson through the *Elements of NGSS Dimensions* pdf and the codes at the beginning of each lesson plan do not have the strikeouts. Due to this inconsistency, the targeted parts of CCC elements for the units are unclear.

Scale, Proportion & Quantity

- *The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.*

- Lesson 4: This element is claimed. In Section 14, students have an opportunity to consider the human impacts of sea level change. One calculation suggests that over 4 million people in the US will be affected. This helps students begin to build an understanding of this element.

- *Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.*
  - Lesson 2: This element is claimed. On page 64, this teacher guidance says, "In this lesson, students only focus on systems that are too slow to observe directly." However, in the lesson flow, there is no explicit emphasis for students on direct versus indirect observations systems. On page 68, the following assessment advice is provided, "Also push to have students identify the readings' specific examples of what indirect evidence sources tell scientists about the past, as these evidence sources are intended to help seed different ideas about what could be affecting global temperatures and, therefore, sea levels."

System and System Models

- *Systems can be designed to do specific tasks.*
  - Lesson 5: This element is claimed. In the lesson, students begin to build an understanding of the two proposed solutions to ice melt at Ilussiat Icefjord, and they develop initial models to try to explain how the design solutions are working. While this implicitly introduces the idea that systems can be designed to do specific tasks, this element is not made explicit to them.
  - Lesson 11: This element is claimed. In Section 6, students are asked "what does our new equation help us explain in this system?" and "how can it help us in addressing glacier melt and sea level rise?" (page 261). Students most likely answer with the idea that the berm system can be designed a specific way, but this element may not be explicit for all students.
- *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.*
  - Lesson 1: This element is claimed. In Section 10, students discuss the following prompts: "Where is matter flowing from and to in our consensus model?," "Where is energy flowing from and to in our consensus model?", and "What object or systems do we care about when thinking about sea level rise?" (page 52). The teacher is told "as students come to agreement on what to define as the system, make a dotted outline around it on the class consensus model." Students identify a system in their model in which they most likely define the boundary. However, students are not asked or supported to think about the initial conditions of the system.
  - Lesson 3: This element is claimed.
    - In Section 5, students engage with pieces of this element as they complete and discuss questions in the *Carbon Dioxide Investigation* handout (page 89). Students identify if carbon dioxide flows into and out of the water bottle system and they describe where the energy comes from, how it gets to the water

bottle, what it does in the bottle, and where it goes. In doing so, students describe inputs and outputs using the physical model set-up. A teacher prompt says "If students have not explicitly stated it yet, ask, What are the boundaries of the water bottle system? How does that compare when thinking about carbon dioxide in the real world? Students should say that the water bottle itself is the boundary here, and the edge of the atmosphere marking the boundary in the real world" (page 89). Students therefore are supported to begin building toward the element, but do not themselves show understanding that the boundaries and initial conditions of the system need to be defined.

  - In Section 9, the class works together to create a model of energy flow in their investigation system (page 93). Students identify inputs and outputs in general terms of energy. However, students do not show evidence of thinking about the initial conditions of the system. They may define the system, as the sample model the teacher draws shows a dotted line, which can be assumed to be the bottle system.

- Lesson 4: This element is claimed. In Sections 10–12, when students conduct an investigation to see the effects of melting ice, students are explicitly told they are investigating a system; however, they are not explicitly supported in engaging with this element. The teacher and handouts in the lesson lead students through calculations (which are called models in the guide) of ice volumes on Greenland and Antarctica and seal level rise associated with melting this ice. However, there is no explicit or emphasized reference to systems, inputs, outputs, and boundaries, or expectation that students will approach sense-making through this lens.
- Lesson 6: This element is claimed.
  - In Section 4, students discuss results from the investigation as a class and are asked "how is the energy flow different in each system?" (page 151). Sample student responses are "energy must stay in the system with darker colors" and "lighter colors must reflect light so the energy does not stay in the system." A margin note tied to this question titled *Supporting Students in Developing and Using Systems and System Models* states, "It is important here to make sure that students are on the same page about what is in the system. In particular, probe the students to get consensus on whether the thermometer is "in" or "out," while establishing that all other surroundings are out of the system." Although the note states to make sure students have consensus about the boundaries of the system, the actual question and sample student responses do not show this understanding. Students also do not show evidence of considering initial conditions.
  - In Section 7, students revise their models from Lesson 5 about how the microbead solution helps slow polar ice melt (pages 155). Students revise a model based on evidence from the investigation and reading to illustrate the relationships between components of a system. The initial conditions of the system are given to students as the Scenario 1 model in the *Revising Prior*

Models handout. The boundary of Earth's system has already been defined for students (through a dotted line). Although all the pieces may not be fully explicit for all students, students most likely engage with the element.

- Lesson 8: This element is claimed.
    - In Section 2, students watch a video about Inuit fishers and hunters and they discuss the questions: "how do these hunters and fishers define system boundaries?" and "how do they describe system inputs and outputs?" Students engage with pieces of the element.
    - In Section 3, students watch a video and read text about NASA's OMG project and they discuss the questions: "how do they define the boundaries of the system?," "how do they describe system inputs and outputs?," and "What are the consequences of drawing the boundaries this way compared to Inuit conceptualizations of the system?" Students engage with pieces of the element.
    - Students complete the *Revisiting Questions and Revising Models* handout. In the handout, students draw dotted lines around boxes that represent key features of the glacier system and then use arrows to depict inputs and outputs. Since these revised model drawings started with an initial model, this implies a consideration of initial conditions.
- Lesson 12: This element is claimed. In Section 3, students use the *Berm Model* handout to develop a model that answers the question, "How much does the berm solution impact energy flows and sea level?" (page 269). However, the ideas of system, boundaries, or conditions are not explicit, so it is unlikely that all students would develop or use this element.
- Lesson 13: This element is claimed. In the transfer task, students are asked to "Define the system. Draw or describe the boundary between the heat pump system and its surroundings" and "use the text, diagrams, and models to explain how the heat pump systems are designed to transfer energy from the outside to the inside." Students therefore need to understand that systems have boundaries and might begin to build toward this high school-level CCC element, but there is not evidence that students need to understand this element (i.e., the importance of defining the boundaries of systems and analyzing and describing their inputs and outputs).

- *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.*
    - Lesson 3: This element is claimed. In Section 7, students conduct the Carbon Dioxide Investigation (pages 91–92). In the investigation, students set up a physical model to simulate a system and interactions to investigate carbon dioxide (matter) and temperature changes (energy). Then in Section 9, students work as a class to develop an energy model (page 93). The teacher is told to "Point out that the water bottle system and Earth system are representing distinct scales, to help us think about how changes at the particle level could add up to significant changes around the world" (page 94), therefore helping students build toward an understanding of this element.

- Lesson 4: This element is not claimed, but a small piece of it is introduced in the lesson. In Section 13, the teacher says, "Our model is an important tool because it can help us think about how sea level rise is actually occurring. However, this simulation does a really good job of reminding us that this is a problem that affects real places and real people" (page 120).
- Lesson 5: This element is claimed. Students begin to build an understanding of the two proposed solutions to ice melt at Ilussiat Icefjord, and they develop initial models to try to explain how the design solutions are working. However, the ideas in this element are not made explicit to them. In Section 8, students share ideas about energy transfer in the models, and the teacher adds their ideas to the class consensus model (page 138). Student ideas most likely involve energy transfer within the system, but the idea of scales is not made explicit, so students most likely use the related Grade 6–8 SEP element: *Models can be used to represent systems and their interactions—such as inputs, processes and outputs— and energy, matter, and information flows within systems.*
- Lesson 10: This element is claimed. In Section 5, the teacher adds energy transfer models that show students' ideas. The model shows energy transfer within a system (pages 231–232). In Section 17, students use a computer simulation of particle motion to study energy transfer from hot to cold objects (page 244). This also shows energy transfer within a system. Since the idea of scales is not made explicit, students most likely use the Grade 6–8 SEP element: *Models can be used to represent systems and their interactions—such as inputs, processes and outputs— and energy, matter, and information flows within systems.*
- Lesson 13: This element is claimed. In Section 6, students use a computer model that simulates a system and interactions. However, the idea of scales is not made explicit, so students most likely engage with the related Grade 6–8 SEP element: *Models can be used to represent systems and their interactions—such as inputs, processes and outputs— and energy, matter, and information flows within systems.*

- *Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.*
    - Lesson 9: This element is claimed. On page 202, the teacher materials say, "Suggest that now that we have exact values for the mass and volume of this sample, we might be able to make a more targeted prediction about their relationship. Remind students of this strategy for developing mathematical and computational models introduced in Lesson 4, which is displayed on the related anchor chart from that lesson: "Predict how big our answers would be and check if they are accurate." These prompts help students build an understanding of the first part of the element. Later, the teacher says, "Plotting all of our data by hand introduces some *error* because we have to line up the coordinate values on the graph by eyeballing them. Even so, for one type of water sample on one graph, a hand-drawn graph can help us see two things: 1) whether the predicted relationship holds, and 2) whether there are any outliers." Although students are

introduced to the idea of error, the specific ideas of accuracy and precision and inherent approximations are not explicitly discussed or used by students.

- Lesson 13: This element is claimed. In Section 2, in the *Modeling the Climate* reading, students read about how climate models make assumptions and different assumptions can result in differences between models. Students discuss the strengths and limitations of climate models (page 282). Students therefore build toward an understanding of this element.

Energy and Matter

- *The total amount of energy and matter in closed systems is conserved.*
  - Lesson 3: This element is claimed. In Section 5, the teacher is told "If students have not explicitly stated it yet, ask, What are the boundaries of the water bottle system? How does that compare when thinking about carbon dioxide in the real world? Students should say that the water bottle itself is the boundary here, and the edge of the atmosphere marking the boundary in the real world" (page 89). In Section 9, students work as a class to develop an energy model (page 93). Students are asked, "did the energy ever disappear?" (page 94) and the teacher then says "We have an interesting idea on the table that the energy does not disappear. Is there a way we could modify our model to show that the energy that went in is the same as the amount of energy at the end?" This can help students begin to build an understanding of part of the element, that the total amount of energy is conserved. However, students do not not effectively consider closed systems.
  - Lesson 10: This element is claimed. In Section 8, during the class discussion about the calculated areas on the graphs, students build an understanding that energy was conserved as it was transferred in a closed system (page 236). In Section 11, students are asked "Was matter conserved in your investigations? How do we know?" The teacher is told to "Point out that scientists have a name for a system where matter is conserved, a closed system. Emphasize that energy can leave a closed system, but matter cannot. Elicit examples of closed systems where energy can still transfer in or out, like a coffee cup with a lid or the bottles in Lesson 3" (page 241). In Section 19, students complete prompts 6–9 in the *Summarizing Our Investigations* handout (page 247). Prompt 6 asks students to "Draw an energy transfer diagram showing energy transfer from warm water to a glacier without a berm present." Some students may use the idea that the total amount of energy in closed systems is conserved.
- *Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.*
  - Lesson 1: This element is claimed.
    - In Section 6 (page 43), Question 4 in the *Initial Model* handout prompts students to "draw a model to show what you think is happening at the particle level to cause the sea level to rise. Make sure your model shows any changes or flows of matter (particles) and energy." However, the idea of systems is not made explicit.

        - In Section 10, students discuss the following prompts: Where is matter flowing from and to in our consensus model? Where is energy flowing from and to in our consensus model?, and What object or systems do we care about when thinking about sea level rise? (page 52). The teacher is also told to make a dotted line around the system as students come to agreement on what to define it as.
    - Lesson 2: This element is claimed. In the "Where We Are Going and NOT Going" section at the beginning of the lesson, teachers are told "In this lesson, students only focus on systems that are too slow to observe directly. They focus on energy flows, returning to matter flows in the context of CCC: 5.2 in Lesson 12. They also do not quantify rates of change and do not think about how some changes are irreversible" (page 62).
        - In Section 7, Students work in groups to analyze and interpret data from three different readings (pages 69–70). Students answer the following questions for each reading: "How did the matter change?" "How did energy flow differently?" and "How could these changes have affected the climate?" In Section 13, the teacher is told to "Point out that here, our system might be different than in Lesson 1, since we are focusing on the whole Earth as the system" (page 72). The teacher models energy flow as a class (page 75). The energy model shows that energy from the sun is transferred by light into the Earth's system where it goes to the ice and particles speed up and ice melts. Students are then asked to discuss how the energy transfer model would change under different conditions (e.g., if there was a major volcanic eruption). There is no explicit focus on the flow of matter. Although in the beginning of the lesson there is an indication to the teacher that matter flows will not be a focus until Lesson 12, the full CCC element is claimed in this lesson.
    - Lesson 8: This element is claimed. In Section 4, the *Revisiting Questions and Revising Models* handout gives students a model about how energy is currently moving in Earth's systems (page 183). Students are given two scenarios (from previous Lesson 5 and 6 models) and they revise the model for each scenario and write hypotheses of what is happening. Students show changes of energy flow into and within the Earth's system and changes in matter within the system.
    - Lesson 12: This element is claimed. In Sections 2–3, students use the *Berm Model* handout to develop a model that answers the question, "How much does the berm solution impact energy flows and sea level?" (page 269). Before making their models, students brainstorm ideas for a Gotta-Have-It Checklist in which they answer questions about where energy is coming from, where it is moving, and how it is affecting matter as it transfers.
- *Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.*
    - Lesson 6: This element is claimed. In Section 4, students discuss results from the investigation as a class and are asked "how is the energy flow different in each system?" and "what do you think causes different energy flows between different materials? Is it

just about colors?" (page 151). Here, students only build an understanding about the transfer of energy and do not yet clearly build an understanding that energy cannot be created or destroyed. On page 157, several guided teacher prompts are offered in relation to polar ice melting. These prompts include: 1) What energy flows would occur in this scenario? Use your finger to trace the energy flows through the model to help students visualize where the energy goes, and 2) Why doesn't the energy just disappear? These prompts build student understanding that energy cannot be destroyed and that it moves within a system.

- Lesson 10: This element is claimed.
    - In Section 8, during the class discussion about the calculated areas on the graphs, students build an understanding that energy was conserved as it was transferred in a closed system (page 236).
    - In Section 10, students use an online simulation to see what happens when two substances of different temperatures touch each other (page 238). Students see what is happening to energy as it moves between objects in a system.
    - In Section 19, students complete prompts 6–9 in the *Summarizing Our Investigations* handout (page 247). Prompt 6 asks students to "Draw an energy transfer diagram showing energy transfer from warm water to a glacier without a berm present." Some students may use the idea that the total amount of energy in closed systems is conserved.

- *Energy drives the cycling of matter within and between systems.*
    - Lesson 9: This element is claimed. In Section 2, students discuss as a class what happens to particles when you add energy to a substance, what happens to the spacing of the particles as the temperature increases, and how they can show this in an energy transfer model. In Section 11, students participate in a class discussion in which they are asked "how do energy and matter work together to affect glacier melt?" (page 216).
    - Lesson 11: This element is claimed. In Section 6, students use the results from their investigation to answer the question "how does heat affect the amount of ice melt?" (page 261). A teacher prompt says, "What does our new equation help us explain in this system?" The equation relates heat of phase change to heat of single-phase temperature change. Since ice and liquid water are matter, and energy changes ice to water, this might be called cycling, but note that it is not explicitly called that in the materials.

Stability and Change

- *Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.*
    - Lesson 1: This element is claimed. In Section 2, when students observe the graph of sea levels, they look at how sea levels have changed since 1900 (page 38). When students answer questions about what they notice about the data and if they think the rate of sea level rise is increasing, decreasing, or staying the same, students implicitly build an understanding of the first part of the element (*Change and rates of changes can be*

quantified and modeled). Later in the lesson when students develop the DQB, the teacher is told "Although students may ask a variety of questions, use this opportunity to assess students' use of crosscutting concepts, especially Stability and Change, as a lens to ask questions that help better understand the particular problem of sea level rise" (page 52).

- Lesson 2: This element is claimed. In Section 11, students work in groups to construct an argument (page 72). The *Where We Are NOT Going* section states, "They (students) also do not quantify rates of change and do not think about how some changes are irreversible (page 64). The *Data Analysis* handout provides an organizational chart for students to record information about the potential different causes they have looked at for recent temperature change. For each cause, students answer the prompts "Did it change at the right time to cause recent temperature increases? Explain" and "Did it change in the right way (direction/rate) to cause recent temperature increases? Explain."
- Lesson 12: This element is claimed. In Section 5, in the *Calculating Berm Impact* handout, students use mathematical models to calculate if the berm could prevent glacier melt (page 272). Students quantify change in the handout, and are asked whether the berm would be able to make the sea level go down again. Students might therefore begin to build toward a small part of this element, but there is no evidence that students would use understanding that some system changes are irreversible.

- *Feedback (negative or positive) can stabilize or destabilize a system.*
  - Lesson 7: This element is claimed. In Section 2, students look at an infographic that shows examples of positive and negative feedback loops in Earth systems (page 168). Students participate in a class discussion in which they learn about the difference between negative and positive feedback and discuss which of the loops make things change and which make things stay the same. However, there is no explicit discussion of stabilization or destabilization.

Suggestions for Improvement

General

- Instead of only writing the codes for the targeted elements at the beginning of each lesson in the "What Students Will Do" section, consider including the text for each targeted element so that it is easier for teachers to navigate and see what the goals of each lesson are. Alternately, the codes in lessons could be linked to a list showing the associated text, since these codes are not present in the NGSS.
- Consider clarifying the claims for the targeted SEP and CCC elements. Including or removing consistent strikeouts in every document could help increase consistency and minimize confusion about the intended learning targets.
- Consider prompting teachers to spend more instructional time in helping students explicitly develop the targeted elements. Currently, a large amount of instructional time is not directly connected to helping students develop proficiency in the targeted elements.

- Consider amplifying and propagating the work done in the Assessment Opportunity call out boxes. These boxes often identify specific student outcomes that are associated with the specific lesson flow in the moment and attempt to link these outcomes to claimed elements. This linking is mostly done by listing some codes associated with full claimed elements and by color coding by dimension. This facilitates matching elements to evidence of development. Consider providing a familiar, repeating structure that links a specific subsections of the targeted elements to student outcomes and to the support to produce those outcomes. This could help busy teachers make the connections to specific parts of claimed elements.

Science and Engineering Practices

- Considering decreasing the number of targeted SEP elements and increasing the number of times an SEP element is addressed in the unit. Of the claimed elements, many are broached in only one or two lessons. It may be difficult for students to develop competence in the complex cognitive skills required for many of the elements if they do not have sufficient in-depth opportunities to engage with each element.
- Consider adjusting claims to clarify where elements are only intended to be introduced, partially developed, or applied from prior learning.

Disciplinary Core Ideas

- Consider decreasing the number of DCIs and increasing the number of times a DCI is addressed in lessons, helping to ensure that students have opportunities to deeply build understanding of the DCI targets.
- In the Elements of NGSS Dimensions document, consider ordering the DCIs in the same way SEPs and CCCs are ordered in the tables such that the progression for each element is clear to users.

Crosscutting Concepts

- Consider choosing a smaller number of CCC elements as learning targets in the unit and providing students with more opportunities to deeply develop and use all of those elements or partial elements in the unit. Implicit exposure to the CCC ideas might not be enough for all students to develop proficiency in applying CCCs as lenses for sense-making. Alternately, consider adjusting claims to clarify where elements are only intended to be introduced or partially developed.

I.C. INTEGRATING THE THREE DIMENSIONS

Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.

Rating for Criterion I.C. Integrating the Three Dimensions	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that student performances integrate elements of the three dimensions in service of figuring out phenomena and/or designing solutions to problems because students have few opportunities to engage in performances that require each of the three dimensions in service of sense-making throughout the unit.

Some examples of three-dimensional performances include:

- Lesson 1: In Section 6 (page 43), Question 4 in the *Initial Model* handout prompts students to "draw a model to show what you think is happening at the particle level to cause the sea level to rise. Make sure your model shows any changes or flows of matter (particles) and energy."
    - Students use part of this **Developing and Using Models** SEP element: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.* The idea of systems is not made explicit. At this point, students do not use evidence in their model.
    - Students use part of this **Energy and Matter** CCC element: *Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.* However, the idea of systems is not made explicit.
    - Students begin to build toward this **PS3.B** DCI element, pulling on their prior knowledge*: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.*
- Lesson 1: This element is claimed. In Section 10, students discuss the following prompts: "Where is matter flowing from and to in our consensus model?," "Where is energy flowing from and to in our consensus model?", and "What object or systems do we care about when thinking about sea level rise?" (page 52). The teacher is told "as students come to agreement on what to define as the system, make a dotted outline around it on the class consensus model." Students identify a system in their model in which they most likely define the boundary. However, students are not asked or supported to think about the initial conditions of the system.
    - Students build toward this **Developing and Using Models** SEP element: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
    - CCC element: *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.*
    - Students begin to build toward this **PS3.B** DCI element, pulling on their prior knowledge*: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.*
- Lesson 2 Section 11: Students work in groups to construct an argument (page 72). The *Data Analysis* handout provides an organizational chart for students to record information about the potential different causes they have looked at for recent temperature change. For each cause,

students answer the prompts "Did it change at the right time to cause recent temperature increases? Explain" and "Did it change in the right way (direction/rate) to cause recent temperature increases? Explain."

- SEP element*: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.*
- CCC element: *Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.*
- Students begin to build toward this **ESS2.A** DCI element, pulling on their prior knowledge: *The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.*

- Lesson 3 Section 9: The class works together to create a model of energy flow in their investigation system (page 93). Students identify inputs and outputs in general terms of energy.
  - Students build toward this **Developing and Using Models** SEP element: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
  - CCC element: *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.* However, students do not show evidence of thinking about the initial conditions of the system. They may define the system, as the sample model the teacher draws shows a dotted line, which can be assumed to be the bottle system.
  - Students begin to build toward this **PS3.B** DCI element*: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.*
- Lesson 6: In Section 7, students revise their models from Lesson 5 about how the microbead solution helps slow polar ice melt (pages 155). Students revise a model based on evidence from the investigation and reading to illustrate the relationships between components of a system. The initial conditions of the system are given to students as the Scenario 1 model in the *Revising Prior Models* handout. The boundary of Earth's system has already been defined for students (through a dotted line).
  - Students use an unclaimed **Developing and Using Models** SEP element: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
  - **Systems and System Models** CCC element: *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.*
  - Students use pieces of **PS3.D** and **ESS2.D** DCI elements.
- Lesson 8: In Section 4, the *Revisiting Questions and Revising Models* handout gives students a model about how energy is currently moving in Earth's systems (page 183). Students are given two scenarios (from previous Lesson 5 and 6 models) and they revise the model for each

scenario and write directional hypotheses of what is happening. Students use the following elements to make sense of energy movement in Earth's systems:

- **Planning and Carrying Out Investigations** SEP element: *Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.*
- Students use an unclaimed **Developing and Using Models** SEP element**:** *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
- Students use some pieces of an **Energy and Matter** CCC element: *Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.*
- Students possibly pull on a foundational part of an **ESS2.A** DCI element as well as part of a **PS3.B** DCI element.

- Lesson 9: On page 202, the teacher materials say, "Suggest that now that we have exact values for the mass and volume of this sample, we might be able to make a more targeted prediction about their relationship. Remind students of this strategy for developing mathematical and computational models introduced in Lesson 4, which is displayed on the related anchor chart from that lesson: "Predict how big our answers would be and check if they are accurate." Later, the teacher says, "Plotting all of our data by hand introduces some *error* because we have to line up the coordinate values on the graph by eyeballing them. Even so, for one type of water sample on one graph, a hand-drawn graph can help us see two things: 1) whether the predicted relationship holds, and 2) whether there are any outliers."
  - SEP element: *Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.*
  - CCC element: *Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.* However, the specific ideas of accuracy and precision and inherent approximations are not explicitly discussed or used by students.
  - DCI element: No high school-level elements are required for this student performance.
- Lesson 12: In Section 3, students use the *Berm Model* handout to develop a model that answers the question, "How much does the berm solution impact energy flows and sea level?" (page 269). Students use parts of the following elements when developing a model to explain the mechanism of the solution:
  - Students use an unclaimed **Developing and Using Models** SEP element: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
  - Some students might implicitly use some pieces of **Systems and System Models** CCC element: *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.* However, the ideas of system, boundaries, or conditions are not explicit, so students are not required to use a high school-level CCC for this performance.

- Students use pieces of a **PS3.A.** DCI element.

Suggestions for Improvement

- See suggestions under Criterion I.B for providing students with more opportunities to engage with grade-appropriate elements of all three dimensions.
- See suggestions under Criterion I.A to help provide students with more opportunities to engage in sense-making and problem solving.

I.D. UNIT COHERENCE

Lessons fit together to target a set of performance expectations.

i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences.
ii. The lessons help students develop toward proficiency in a targeted set of performance expectations.

Rating for Criterion I.D. Unit Coherence	Inadequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that lessons fit together coherently to target a set of performance expectations. Although the lessons are thematically linked and student questions are elicited and revisited, the lessons do not work together to help students develop proficiency in most of the targeted PEs.

The lessons are linked through the themes of rising sea levels and glacier melt. The teacher often helps students see how the lessons connect by revisiting work done in previous lessons and by using different tools and strategies provided. Related evidence includes:

- The unit materials establish a navigation routine often found at the beginning of end of lessons. At the beginning of Lesson 2, students are told, "We will often begin or end a lesson, or even a day, with the Navigation Routine. We use navigation to help us remember what we figured out the last time we met and decide what we should do next to answer the questions that we still have" (page 65). Some examples include:
    - Lesson 2: At the beginning of the lesson, students discuss what they decided they wanted to figure out in the last lesson (page 65).
    - Lesson 4: The beginning of the lesson states "Navigate into today's work by revisiting the model students built last class" (page 107). In Slide A, students discuss what they have figured out so far about why sea levels are rising.
    - Lesson 6: At the beginning of the lesson, students revisit which question(s) they were most interested in at the end of Lesson 5 (page 148). "Help students recall where Lesson 5 left off. Display slide A and the Driving Question Board. Have students turn and talk around the prompts on the slide for a couple of minutes before discussing them as a class."
    - Lesson 10: At the beginning of the lesson, students are reminded of what they focused on during the last lesson and what they were still wondering (page 226).
- The Progress Tracker is used in the unit to help students organize what they have learned. Some examples include:
    - Lesson 2: In Section 14, students set up their Progress Tracker and then write the lesson question (what can the past help us figure out about what is causing sea level rise in the present?) in the left column and write what they have figured out related to the question in the right column (page 77).
    - Lesson 4: In Section 15, students update their progress tracker for the question "what would happen if the Earth's ice melted?" (page 123).
    - Lesson 6: In Section 10, students update their progress tracker for the question "why would some engineers want to sprinkle glass microbeads on the Artic?" (page 159).
    - Lesson 9: In Section 10, students update their progress tracker for the question "why does warm salty water sink to melt a glacier?" (page 214).
    - Lesson 11: In Section 6, students update their progress tracker for the question "how does heat affect the amount of ice melt?" (page 261).
- Although the navigation routines and the progress tracker help students see topical connections across the unit, students may not always connect their lesson-level focus back to sense-making of the anchor phenomenon. After the anchor phenomenon is introduced, the unit introduces topics such as: sea level rise from many thousands of years ago, carbon dioxide's role in climate change, calculating sea level changes if land ice melts, figuring out how to slow glacier melting

with a berm, how to slow glacial melting with glass beads, thinking about feedback loops, determining fluid densities, simulating heat transfer with a computer, calculating the amount of heat to melt a glacier, and using a climate model. Some supports are provided to help students connect these topics to the anchor phenomenon. For example, in Lesson 7, the teacher is told to "Briefly discuss how permafrost fits with the anchoring phenomenon. Ask, What does this new understanding of permafrost tell us about sea level rise specifically and climate change generally?

Student questions are elicited throughout the unit, a DQB is created, and these questions are often revisited and added to. Some examples include:

- Lesson 1: In Section 11, students write down new questions that they have about the phenomenon (page 53). They share their questions with the class and the teacher develops a Driving Question Board (DQB). The teacher is instructed to, "Propose that these questions are all related to an overarching question, such as, "How can we slow the flow of energy on Earth to protect vulnerable coastal communities?" Title the DQB with this question or a similar one as phrased by your students" (page 54).
    - Lesson 3: In Section 13, students revisit the DQB and put a checkmark on questions they have answered and stars on questions they think should be investigated next (page 98). Students also add any additional questions they have.
    - Lesson 5: In Section 10, students add new questions they have about the proposed design solutions to the DQB (page 140).
    - Lesson 7: In Section 4, students revisit the DQB (page 170). They mark the questions they think they have answered, have only answered some parts of, and have not answered. Students add additional questions.
    - Lesson 13: In Section 8, students return to the DQB (page 285). They mark the questions they think they have answered, have only answered some parts of, and have not answered.
- Lesson 3: In Section 10, students share their questions they still have about the effects of carbon dioxide on Earth systems, and at the beginning of Section 11, the teacher is told to "use students' questions from the previous activity to introduce the reading" (page 96).
- Lesson 3: In Section 11, students record and then share any questions they have about the *Atmospheric Carbon Dioxide* reading (pages 96–97).
- Lesson 5: In Sections 7–8, the teacher is told to keep track of student questions about the proposed solutions (pages 137–138).
- Lesson 8: In Section 1, students develop questions about what is going on where the glacial ice meets the ocean water (page 177). In Section 4, students revisit the questions and answer the question "how might what we have learned help to answer the questions you had at the start of the lesson?"

The following NGSS Performance Expectations (PEs) are identified as learning targets for the unit. While students have opportunities to build toward proficiency in some of the elements associated with the PEs claimed, students do not have enough opportunities to build toward full proficiency in the elements associated with three PEs that are only developed in this unit as described in the list below:

- **HS-PS3-1†** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flow in and out of the system are known.
- **HS-PS3-4** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
- **HS-ESS2-2** Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.
- **HS-ESS2-4*** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- **HS-ESS2-7†** Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.
- **HS-ESS3-1*** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- **HS-ESS3-5** 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 on Earth systems.
- **HS-ESS3-6†** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Note that the SEP elements associated with HS-ESS2-2 and HS-ESS3-5 are also not claimed as SEP learning targets for the unit, although HS-ESS2-2 and HS-ESS3-5 are not marked in the list copied above as being developed across multiple units. Page 10 states that "HS-PS3-4, HS-ESS2-2, HS-ESS2-4, HS-ESS3-1, and HS-ESS3-5 are addressed in this unit alone in the OpenSciEd course sequence," which contradicts the notations next to HS-ESS2-4 and HS-ESS3-1 in the box on page 13, as well as the description of HS-ESS2-2 and HS-ESS3-5 being partially developed in another unit. As a result, the learning goals for this unit are unclear.

Suggestions for Improvement

- Consider providing students opportunities to develop and use the SEP elements associated with HS-PS3-4 and HS-ESS3-5 and claiming these elements as learning targets for the unit.
- Consider sequencing the unit from a student's perspective, especially the sequencing of tasks and topics that students are required to do.
- Clarifying which PEs are the learning targets of only this unit could help clarify claims.

I.E. MULTIPLE SCIENCE DOMAINS

When appropriate, links are made across the science domains of life science, physical science and Earth and space science.

i. Disciplinary core ideas from different disciplines are used together to explain phenomena.

ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems across science domains is highlighted.

Rating for Criterion I.E. Multiple Science Domains	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that links are made across the science domains when appropriate. DCIs from both ESS and PS are identified as learning targets for the unit, and students need to use ideas from both domains to explain some of the phenomena. However, there isn't evidence that it is always clear to students how the ideas from ESS and PS work together to explain the phenomena. In addition, crosscutting concept use across the science domains is not highlighted or made explicit to students.

In Lesson 5, students have an opportunity to link DCIs from ESS and PS to make sense of the two proposed solutions for slowing the melt rate of a glacier in Greenland. However, this connection is not made explicit to students.

Crosscutting concept use across the science domains is not highlighted or made explicit to students. Related evidence includes:

- Students use pieces of **System and System Models** CCC elements to help make sense of both ESS and PS DCIs throughout the unit. However, this use across domains is not made explicit to students.
- Lesson 3: The "Where We Are Going and NOT Going" section tells the teacher "Students are building on prior understandings about energy not being created or destroyed (that is, being conserved) from OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit). This experience was in the context of ecosystems, so this unit helps systematize the thinking more, beginning in this lesson as energy conservation is brought into physical systems" (page 84). However, this discussion is not made explicit for the students.

Suggestions for Improvement

- Consider helping students explicitly recognize when they are using ESS and PS concepts together to explain the phenomenon.

- Consider providing supports for students to see how the same CCC element is useful for sense-making or problem solving related to different science disciplines. This could include making explicit references to students' prior learning.

I.F. MATH AND ELA

Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.

Rating for Criterion I.F. Math and ELA	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials provide grade-appropriate connections to the Common Core State Standards (CCSS) in mathematics, English language arts (ELA), history, social studies, or technical standards because the unit identifies multiple mathematics and ELA standards that students engage with in the lessons, and there is evidence that these standards are used in the unit. The materials make the use and importance of mathematics in understanding science concepts explicit for the student.

Related evidence includes:

- The *Unit Overview* document identifies connections to mathematics (pages 20–21). "This unit does not assume students are fluent with the mathematical practices listed below, but that students develop these practices as part of the sense-making. Thus these standards are not so much prerequisites, as co-requisites. If students are simultaneously developing the skills and vocabulary in math class, you can help by making explicit connections to the mathematical standards below."
- A section titled "What mathematics concepts will students engage with in the unit?" provides a table with details of mathematical concepts and skills used in specific lessons (pages 20–21).
- The materials make the use and importance of mathematics in understanding science concepts explicit to students. Some examples include:
    - The teacher is prompted to develop and update a Mathematical Anchor Chart throughout the unit to help students keep track of mathematical concepts they are learning.
    - Lesson 9: In Section 5, the teacher asks students to recall a line of best fit from their prior mathematics work, and then in Section 6, the teacher leads a discussion about what the lines and slopes mean in the context of what they are measuring in their lab (pages 204–205).

- Each lesson identifies the mathematics and ELA standards that it claims students are using in that lesson. There is evidence that students engage with these standards. Some examples include:
    - In Lesson 3
        - CCSS.ELA-LITERACY.RST.9-10.2: Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
            - In Section 11, students summarize the ideas from the *Atmospheric Carbon Dioxide* reading.
        - CCSS.ELA-LITERACY.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
            - Students follow an experimental procedure in which they take measurements.
    - In Lesson 7
        - CCSS.ELA-LITERACY.RST.9-10.7: ~~Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and~~ translate information expressed visually ~~or mathematically (e.g., in an equation)~~ into words.
            - Students describe in words what they see in the positive and negative feedback loops in *Earth's Feedback Loops* infographic.
    - In Lesson 8
        - CCSS.ELA-LITERACY.RST.9-10.7: ~~Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and~~ translate information expressed visually ~~or mathematically (e.g., in an equation)~~ into words.
            - Students describe findings from the graphics in the NASA OMG project in words.
        - CCSS.ELA-LITERACY.RST.9-10.9: Compare and contrast findings presented in a text to those from other sources ~~(including their own experiments~~), noting when the findings support or contradict previous explanations or accounts.
            - Students compare and contrast the methodologies and findings of Inuit hunters and fishers with those of NASA researchers.

Suggestions for Improvement

N/A

OVERALL CATEGORY I SCORE: **2** (0, 1, 2, 3)	
Unit Scoring Guide – Category I	
Criteria A-F	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

CATEGORY II

NGSS INSTRUCTIONAL SUPPORTS

II.A. RELEVANCE AND AUTHENTICITY

II.B. STUDENT IDEAS

II.C. BUILDING PROGRESSIONS

II.D. SCIENTIFIC ACCURACY

II.E. DIFFERENTIATED INSTRUCTION

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

II.A. RELEVANCE AND AUTHENTICITY

Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world.

i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations).

ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate.

iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.

Rating for Criterion II.A. Relevance and Authenticity	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials engage students in authentic and meaningful scenarios that reflect the real world. All students have opportunities to directly experience the phenomena through various media formats and the phenomena are embedded in real-world contexts. The materials include suggestions for how students can connect some learning to their experiences and lives.

Students experience the phenomena through texts, videos, images, and graphs. The phenomenon of rising sea levels, which affect communities around the world, is embedded in real-world contexts. Some examples include:

- Lesson 1: In Section 1, students watch three videos about three different locations in the world that have been affected by sea-level changes (page 35).
- Lesson 1: In Section 2, students observe a graph that shows that sea levels have increased from 1990 to now (page 38).
- Lesson 1: In Section 3, students observe a world map that shows likely sea level rise and then view images that show how three different places would be affected by about three feet of sea level rise (page 39).
- Lesson 5: In Section 2, students observe photos and watch a video that depicts the melting of the Ilulissat Glacier (page 132).

The unit includes suggestions for how to connect instruction to students' communities and lives. Students have opportunities to connect their learning to other phenomena from their experiences. However, students are not prompted to ask questions that are connected to their experiences and lives. Also, it is not clear whether students would relate and experience connections to their own culture. Related evidence includes:

- There is a protocol offered to teachers named "Learning in Places socio-ecological deliberation and decision-making framework" on page 24. The protocol engenders thinking about other cultures, especially in reference to natural phenomena like sea level rise.
- Lesson 1: Language is used to respect indigenous communities: "You will notice many places have two names in this unit. In all of these cases, one name is an Indigenous name, and the other name is a settler name. Throughout the unit, OpenSciEd has made an effort to use the Indigenous names of places. We will use callouts to highlight the history of these places and names. If you are trying to search for the locations on Google, you may need to use the settler name" (page 36).
- Lesson 1: An *Attending to Equity* margin note states "Work to ensure that students who do not live near the coast build connections to the communities examined here. Besides the humanity of those who are affected and the importance of their culture, if necessary also bring in ideas about fishing and other economic services these communities provide and the financial and social consequences of many people having to move to another place in a short period of time" (page 39).
- Lesson 1: In Section 1, when the teacher facilitates an initial ideas discussion, a *Strategies for This Initial Discussion* margin note states that, "Make space for all students to share their ideas (possibly connected to experiences they have had outside school as well)" (page 36). This may result in students having an opportunity to share their personal experiences.
- Lesson 1: In Section 5, student experiences related to changing water levels are elicited when students are asked to discuss the following question: "what are other examples you have encountered when the level of water has changed over time?" (page 42).
- Lesson 4: In the Exit Ticket students are asked, "In this lesson, we brainstormed different possible solutions to help slow or stop sea level rise. Why might these solutions be important to you, whether you live near the ocean or not?" (page 336). The Assessment System Overview (page 289) for the Exit Ticket states, "Students also have an opportunity here to reflect on why it is important to address sea level rise and engage with metacognitive questions around their own lives."
- Lesson 10: In Section 13, for an at home activity, students are asked to "document additional phenomena that the updated simulation could explain" (page 242). Students discuss the additional phenomena in class the next day.
- Some students may be unable to authentically relate/connect to the importance of completing the many calculations in the unit. However, in Lesson 4, the teacher prompts, "How do you feel about these likely impacts, and about even greater potential impacts?" The posited student response is, "We feel bad for people who are affected," which shows an example of students relating.

Guidance is provided to the teacher for how to address issues of student concerns and sensitivities if they arise in the classroom:

- The *Unit Overview* document has a section titled *How do I support students' emotional needs?* (page 23). This section states that some students may struggle with climate anxiety or may identify as a refugee/migrant from human caused or natural disasters. The section suggests ways to address these issues including reaching out to a counselor for "student-specific support and strategies."

- Lesson 1: An *Attending to Equity* margin note states "Discussion around the terminology used to describe people displaced by climate change is especially important if you have students who are considered refugees. The term refugee can have negative connotations. As you facilitate this discussion with students, remind them that as they share their ideas they should be considerate and mindful of the possible struggles of others. Climate refugee will be the term used throughout the unit to describe people who are displaced due to climate change. If your class decides on a different term, be sure to substitute it whenever you see climate refugees referenced in materials. This could be an SEL connection to the CASEL core competency, Social Awareness" (page 41).

Suggestions for Improvement

- Consider prompting students to explicitly draw on their prior experiences and culture when they formulate questions.
- Consider showing teachers what to look for to observe and evaluate all important aspects of authenticity and relevance. This could look like exemplar student responses or actions that teachers can use to confirm whether or not students are authentically engaged and can make connections to their own cultures.

II.B. STUDENT IDEAS

Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate.

Rating for Criterion II.B. Student Ideas	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials provide students with opportunities to both share their ideas and thinking and respond to feedback on their ideas. Students have multiple opportunities to express, represent, and clarify their ideas. However, most of the feedback opportunities are optional, which does not guarantee that all students will receive meaningful feedback, and it is not clear if many of students' own ideas are truly elicited vs. heavily hinted from the teacher.

Students have opportunities to express, clarify, and represent their ideas. Note that most of the work completed and artifacts generated are completed as partner, class, or group work, so not all students may have sufficient opportunities to fully express their ideas. Some examples include:

- Lesson 1: In Section 7, students participate in a Concentric Circles discussion strategy (page 45). Students discuss the similarities and differences in their initial models and write them down in their science notebook. Students then share the similarities and differences with the class (page 48).
- Lesson 1: In Section 9, the students work as a class to develop an initial consensus model (page 48). The teacher facilitates a discussion and records the consensus model on chart paper while encouraging students to identify their evidence and reasoning.
- Lesson 2: In Section 7, Students work in groups to analyze and interpret data from three different readings (pages 69–70). Students participate in a Chalk Talk, in which they start at the first poster, answer questions, and then rotate to the next poster. In Section 8, students participate in a gallery walk, during which they examine the posters and record notes on each poster using one of the provided sentence starters (e.g., this poster made me think differently about energy because…"
- Lesson 5: Students are given two solutions to slow the melt rate of a Greenland glacier (page 134). Teacher guidance says, "After listening to the quotes, give students a few minutes to reflect in their notebook about the following: Who will be impacted by the decision and how? What potential impacts resonate with you? What do you wonder?" An opportunity to see if student thinking has changed over time can be found by looking at a lesson where the final solution to this problem is discussed. In Lesson 12 the teacher prompt is, "Say, Let's think more about this solution. Lead students in a brief discussion beginning with the prompt on the slide, then continue with the additional prompts below" (page 273). Example student answers that relate to who might be impacted include: "No, because it might not be supported by local people. No, because it might be harder to stop the water in certain locations. No, because in some places, more of the melting might be due to the air, the ground, or the Sun. No, because there might be scenarios where it affects wildlife."
- Lesson 5: In Section 5, students share their initial energy transfer models with group members who modeled the other design solution (page 135). Then in Section 7, students share their ideas about the initial models with the class to build an initial class consensus model (page 136). A margin note suggests to support collaboration by asking questions such as, "Does anyone disagree with the idea presented?"
- Lesson 9: In Section 2, students create initial particle models with a partner and then discuss as a class (page 196).

There are opportunities for students to receive peer and teacher feedback. However, most of these opportunities are optional, so there is less evidence that all students will receive feedback to reflect upon. Some examples include:

- The *Assessment Overview Section* states that a peer assessment resource is available in the *OpenSciEd Teacher Handbook* and that "we suggest that peer review happen at least two times per unit" and "Recommendations for moments in which to use the peer assessment tool may be found in Lessons 2, 4, 9, and 12" (page 292).
- Lesson 2: In Section 11, the *Collaboration* box suggests that as an alternative, students could complete the *Data Analysis* handout individually or with a partner and then "use peer feedback

protocols described in the *OpenSciEd High School Teacher Handbook* to give each other feedback" (page 72). Since this is an optional activity, students may not have an opportunity to receive peer feedback.

- Lesson 4: In Section 6, the *Collaboration* box suggests that this can be an opportunity for students to provide peer feedback using the protocols in the *OpenSciEd High School Teacher Handbook* (page 112). This seems like an optional activity, so all students may not have an opportunity to receive peer feedback.
- Lesson 4: In Section 10, the *Alternate Activity* box suggests that if there is extra time, one of the options can be to ask students to provide peer feedback on each other's calculations (page 118). This is an optional activity, so all students may not have an opportunity to receive peer feedback.
- Lesson 9: Page 215 states "Turn and Talk. Display slide Y and ask students to take out Revisiting Questions and Revising Models from last class. Invite students to add to their models as they turn and talk with a partner." The *Collaboration* box below this step states "Students should be becoming more independent in energy transfer modeling at this point. If you wish to see where students are individually, this can be an opportunity for students to provide peer feedback using the protocols shared in the OpenSciEd High School Teacher Handbook. Have students begin this work individually, then share with a partner using the peer feedback protocol." All students will receive an unstructured opportunity to share and revise their models with a partner here, although it is optional for students to receive structured peer feedback using the protocols.
- Lesson 12: In Section 4, the *Collaboration* box states, "Before students build a class consensus model, you may wish to give them an opportunity to share and sharpen their work through peer feedback" (page 270). This is an optional activity, so all students may not have an opportunity to receive peer feedback.
- Lesson 12: In Section 4, the *Assessment Opportunity* box suggests to the teacher "You may wish to collect individual students' models once they have had a chance to revise them. If so, the recommendations provided on the key for Berm Model may be helpful for providing feedback" (page 272). This is optional, so all students may not have an opportunity to receive teacher feedback.
- Lesson 12: In Section 8, the *Assessment Opportunity* box suggests that the teacher "may wish to provide feedback that asks probing questions that help students identify gaps in their reasoning that can be investigated using the computational model in Lesson 13" (page 275). This is optional, so all students may not have an opportunity to receive teacher feedback.

Suggestions for Improvement

- Consider integrating at least some of the optional feedback opportunities so that they are part of the main instructional plan. This can help ensure that all students receive feedback.
- Consider providing activity-specific guidance and structure for how peers and teachers can provide feedback and how students can reflect upon and use the feedback. This could help make the feedback process more meaningful.
- Consider helping teachers track how students' own ideas develop over time, providing a range of trajectories of possible student thought. For example, some students might initially think that

we should just move the coastal people. But as the unit develops, students might internalize how energy transfers make the problem much larger than just a coastal town. Student thinking might evolve to the point where solutions for the coastal towns early in the unit imply solutions for the planet. Consider guiding the teacher to look for and monitor this sort of change in ideas.

II.C. BUILDING PROGRESSIONS

Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers:

i. Explicitly identifying prior student learning expected for all three dimensions
ii. Clearly explaining how the prior learning will be built upon.

Rating for Criterion II.C. Building Progressions	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials identify and build on students' prior learning in all three dimensions because the unit identifies elements that students should have prior knowledge of and includes some basic learning progressions for some of the elements. However, the materials do not provide detail on how specific SEP and CCC elements form an identifiable progression across the unit.

The unit materials identify prior learning for DCIs, SEPs, and CCCs. Prior learning is identified at the category, element, and PE levels. Some examples include:

- The *Unit Overview* document (Unit Overview, page 16) includes a section titled *How does the unit build three-dimensional progressions across the course and the program?* The section identifies some prior learning. Some examples include:
    - The section identifies two DCI elements that students should have previously developed in OpenSciEd High School Biology and says that it uses and builds upon those elements and then states "Although students should be familiar with the second point from OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit), in this unit it *is* further emphasized, along with debunking of other "alternate explanations" for climate change on Earth, to ensure that students are engaging with the rest of the unit from the same set of base assumptions. This unit expands on the work done in OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit) by expanding the mechanism for

the enhanced greenhouse effect and comparing the role of carbon dioxide to other factors that can impact energy flows on Earth and therefore global climate."
- The section identifies middle school DCI elements and claims, "This unit reinforces and builds from the following disciplinary core ideas (DCIs) and other science ideas from the OpenSciEd Middle School sequence." However, a description is not provided for how that building and reinforcing takes place.
- In this section, prior and future high school instructional units in which each SEP category was or will be developed are identified.
- In this section, prior and future high school instructional units in which each CCC category was or will be developed are identified.

- The *Unit Overview* Document states that the unit is the first in the High School Chemistry course sequence (Unit Overview, page 10). It also lists which PEs are shared across other units across the OpenSciEd High School courses, "HS-PS3-1 is shared with OpenSciEd Unit C.5: Energy from Chemical & Nuclear Reactions (Chemical Energy Unit), OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit), and OpenSciEd Unit P.4: Meteors, Orbits, and Gravity (Meteors Unit)…HS-PS3-4, HS-ESS2-2, HS-ESS2-4, HS-ESS3-1, and HS-ESS3-5 are addressed in this unit alone in the OpenSciEd course sequence"

The *Unit Overview* Document identifies several common ideas students might have when they enter the unit (Unit Overview, page 19).

The unit materials provide some progressions for DCI understanding. Some examples include:

- The *What elements of the NGSS three dimensions are developed in this unit?* section (pages 13–14) identifies a basic progression of topics and activities students will encounter in the unit. Several words that can relate to DCI categories such as "energy transfer" and "conservation" are highlighted in orange. However, individual elements are not identified, and the learning progression of individual elements is not described.
- Lesson 1: The *Where We Are NOT Going* section states: "Students will not have the evidence to fully support the idea that sea levels are rising due to polar ice melt until Lesson 2 and will re-develop and extend middle school mechanisms for energy transfer in Lessons 3 and 6 (radiation), 9 (convection), and 10–11 (conduction). However, in this lesson students should begin to recognize polar ice melt as a possible cause and ideate how energy flows could be causing changes in the number of water particles in the ocean or the space that they take up. Students do not have to know the molecular structure of water in order to do this thinking. Molecular structures and terminology for different categories of substances (pure substance vs. mixture) are introduced in Lesson 3" (page 33).

The unit materials provide some progressions for SEP understanding. However, these progressions often do not track a single claimed element along a trajectory of increased learning. Rather, they usually comment on several elements, so teachers may have difficulty understanding how student performance in a given claimed element progresses. Some examples include:

- Lesson 1: The Where We Are Going section states: "In this lesson, students' use of asking questions builds on their work in this practice in biology, particularly in OpenSciEd Unit B.3: Who gets cancer and why? Where should we focus efforts on treatment and prevention? (Genetics Unit). Students have prior experience in developing and using models from OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit), OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit), and OpenSciEd Unit B.3: Who gets cancer and why? Where should we focus efforts on treatment and prevention? (Genetics Unit)" (page 33).
- Lesson 2: The Where We Are Going section states: "Students interpret curated data (SEP: 4.5) for purposes of revising their existing model and constructing an argument (SEP: 7.2) about which of the various factors could be causing current temperature increases. Analyzing and interpreting data was previously developed in OpenSciEd Unit B.4: How is urbanization a driving force of evolution? Should we design urban spaces more hospitably for non-human species? (Evolution 1 Unit) and engaging in argument from evidence in Speciation Unit" (page 64).
- Lesson 2: In Section 2, the *Supporting Students in Engaging in Analyzing and Interpreting Data* margin note states that the activity assumes students "have experience with analyzing graphical data from OpenSciEd High School Biology and middle school course work" (page 65). However, the level of proficiency or which specific elements students have prior knowledge of are not identified. The note does suggest a resource if students "need more support."
- Lesson 3: The Where We Are Going section states, "This lesson is students' first experience in this unit planning and carrying out investigations. Although they have previously developed this practice at the high school level in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*, they can now develop this practice in a chemistry laboratory environment and with increasingly complex investigations. *Investigation Anchor Chart* tracks how students build this practice throughout the course" (page 84). While this states that students have engaged with planning and carrying out investigations in a previous high school unit, in Lesson 3 Section 4, the teacher is told to "introduce the concept of a scientific investigation question" (page 86). Students should already have an understanding of what an investigation question is from the previous unit and from previous grade-bands. In Section 4, the teacher is also told to "pause to define the three variables and write the definitions on the anchor chart." This step is not framed as review.
- Lesson 8: The Where We Are Going section states, "Students have previously developed the practice of obtaining, evaluating, and communicating information at the high school level in *OpenSciEd Unit B.5: How did polar bears evolve and what will happen to them as their environment changes? (Natural Selection Unit)*. They will continue to develop this important practice in *OpenSciEd Unit C.2: Structure & Properties of Matter (Electrostatics Unit)*" (page 176). Therefore, teachers are told in which units this elements will be used. On the same page, the teacher is told "Whereas in earlier lessons students asked questions, arising from models and unexpected results, that were possible to investigate with available materials in a laboratory setting, in this lesson students ask questions that must be answered by gathering evidence from the field". This describes in which lessons different elements of this SEP categories will be used. However, whether or not students learn something new is not described.

The unit materials provide some progressions for CCC understanding. However, these progressions often do not track a single claimed element along a trajectory of increasing learning. Rather, they usually comment activities in which several elements may be used, so teachers may have difficulty understanding how student performance in a given claimed element progresses. Some examples include:

- Lesson 1: The Where We Are Going section states: "They developed the crosscutting concept of stability and change in OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit), energy and matter in OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit), and systems and system models in OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)" (page 33). Only prior learning is described.
- Lesson 2: The *Where We Are Going* section states: "Students engage with the crosscutting concept of scale (CCC: 3.2), previously developed in OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit) and OpenSciEd Unit B.5: How did polar bears evolve and what will happen to them as their environment changes? (Natural Selection Unit), to figure out how scientists have developed a strong understanding of how Earth systems have operated throughout history, and the crosscutting concept of stability and change (CCC: 7.2) to identify that alternative factors do not explain current global temperature increases" (page 64). Only application of prior learning is described.

Suggestions for Improvement

- Consider explicitly describing learning progressions for elements of all three dimensions, especially in terms of how learning is expected to be enhanced as a direct result of some specific action within a lesson. This would support teachers to not only be able to identify progressions, but to link them to the day-to-day learning artifacts that their students produce.
- Consider developing a graphic that depicts how a CCC element develops across lessons. The graphic could include key phrases from targeted lesson or essential actions that result in student artifacts of learning. Without this kind of guidance, it might be difficult for teachers to keep track of how an idea "CUTS ACROSS" several learning experiences. The design of the graphic might show how learning and skill development in an early instance of the CCC fosters enhanced learning in the next instance and so on.

II.D. SCIENTIFIC ACCURACY

Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.	
Rating for Criterion II.D. Scientific Accuracy	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials use scientifically accurate and grade appropriate scientific information because all disciplinary material is accurate. However, it is possible that materials could lead students to misconceptions about the nature of science.

Related evidence includes:

- Page 37 of Lesson 1 states, "Identify local causes for the changes in sea level rise and the reason people have to move. Say, So the people in these communities are already being affected by sea level rise! If we know what is causing it, maybe we can understand how to stop it. The videos stated that there are some local reasons for why sea levels are rising. What are the local reasons for the Biloxi-Chitimacha- Choctaw community to have to move? What about coastal communities in Senegal or Sierra Leone? Add the answers to these questions to the Notice and Wonder chart. Student answers might include tropical cyclones/hurricanes, rainfall, and coastal erosion." A clear distinction between local sea level rise (due to surges, flash flooding from storms, etc.) and general sea level rise (due to climate change) is not made for students. Although it can be helpful to not immediately correct students' initial ideas behind sea level rise, the discussion of local causes for sea level rise does not explicitly occur again in the unit, so this could possibly lead to the students having the misconception that cyclones/hurricanes are causing general sea levels to rise.
- Lesson 6: The answer key to the *Revising Prior Models* handout leaves out some arrows (in addition to those it identifies as leaving out purposefully) and does not accurately label the arrows, leading to scientific inaccuracies. For example, the arrow coming from the Sun is only labeled with visible light, which is inaccurate. The arrow could mention other common forms of radiation, such as infrared, ultraviolet, or "other" radiation.
- In Lesson 12, pages 269–273, the teachers uses scripted prompts to sketch the way heat energy flows in the "berm solution" to the fast-melting glacier in Greenland. The section title is "Build a Consensus Model". What follows is a tightly scripted set of teacher prompts that leave very little room for students to say or think anything but what the teacher already had in mind. This process is meant to result in in student responses as posited by the teacher guide. Then the materials tell the teacher to, "Add these ideas to the consensus model chart paper." The teacher has already drawn the berm model and now adds what the teacher thinks is the set of answers. It seems this process is called a consensus, which might reinforce the misconception that being presented information and/or being led to a predetermined result is the same as consensus. The teacher hands out a worksheet that leads students through several calculations regarding the berm solution. At the end, the worksheet says, "Would the design solution you have been evaluating to block the flow of warm water into the ice fjord stop enough energy transfer to

prevent **all** of the melt occurring at Ilulissat Glacier, or only **some** of it?" Because of the way this summarizing statement is presented, it is possible that students might think the calculations are definitive or even the same as empirical evidence. In effect, students might think that the worksheet protocol takes the place of valid and reliable evidence gathering and interpretation accompanied by thoughtful skepticism, especially since it is unclear to the students where the worksheet data come from. Presenting model results without the context of verification through observation might send the wrong message and decrease appropriate scientific skepticism. In part, this idea of skepticism is represented by the NGSS Understandings of the Nature of Science element 1.3, which states, "Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review."

- In Lesson 13, students interact with a computer-based climate algorithm. The associated reading says the algorithm is based on equations and assumptions, none of which are presented, but are supposed to be analogous to the berm-model use of equations. Students manipulate icons on a board-game like screen to determine what this algorithm produces as numerical outputs. Students ask questions that can be addressed by bi-variate graphs produced by the algorithm. But the algorithm is a black box to students. This dependence of the unit on a process and tool that is inaccessible and unknowable to students might lead to the misconception that algorithms are reality. The materials do not teach how to be skeptical or challenge ideas or results, especially results that come from "black box" sources. The potential result is that students view results told to them by a screen as canonical.
- In the unit, students do not learn that glacier calving is a natural process, which could result in promoting student misconceptions.

Suggestions for Improvement

- Consider modifying the answer key in Lesson 6 to be scientifically accurate at a grade-appropriate level.
- Consider modifying the discussion about local causes for sea level rise in Lesson 1.
- Since the current consensus discussions are organized to lead students to pre-determined goals, consider changing the name of the discussions. Names such as "ideas in progress" might more accurately capture the idea that the discussions are not necessarily "consensus" from students' own independent ideas.

II.E. DIFFERENTIATED INSTRUCTION

Provides guidance for teachers to support differentiated instruction by including:

i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level.

ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations.

iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.

Rating for Criterion II.E. Differentiated Instruction	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide guidance for teachers to support differentiated instruction because the materials provide extensions and explicitly describe differentiation strategies for students who may be struggling to meet the goals and for multi-lingual learners. However, the materials do not provide individualized learning strategies that support students in three-dimensional sense-making.

Some support is provided for students who are multilingual or who may be struggling. Some examples include:

- In the *Unit Overview Document* (page 19) there are three sections with different titles, "How will I need to modify the unit if taught out of sequence?" and "How do I shorten or condense the unit if needed? How can I extend the unit if needed?" and "What strategies are available to support equitable science learning in this unit?" Each section suggests how to adapt materials for students either for time reasons or for any occasion or situation that might require specialized instruction. The specialized (differentiated) instructions are detailed in the lesson flow in the right-hand margin. The strategies provided include: Attending to Equity, Supporting Emerging Multilingual Learners, Supporting Universal Design for Learning, Additional Guidance, Alternate Activity, and Key Ideas callouts.
- Lesson 1: An *Alternate Activity* box in Section 4 states, "For students who benefit from additional reading support, you can prompt them to highlight specific parts of the text in different colors, e.g., highlight the "*who*" in yellow, the "*why*" in blue, and the "*where*" in orange. This will provide a focus for reading and clarify similarities and differences between the terms. *Who* = refugee, migrant, climate migrant; *Why* = fear of persecution for various reasons, any reason, displaced by the effects of climate change; *Where* = outside of their own country or residence" (page 41).
- Lesson 1: There is teacher support regarding students making a sketch that shows their current thinking: "Students often struggle with their initial attempts at modeling. Remind students that this is an opportunity to share initial ideas and that you do not expect perfection. Also,

encourage students to think about how the related phenomena can be explained and if sea level is rising for similar reasons" (page 245). The materials explicitly show what to anticipate, but there is no model-specific teacher support for the struggle mentioned, only the strategy "to encourage" and "think about".

- Lesson 2: Support after the teacher asks a question says, "If students struggle to generate ideas, follow up with, How do scientists, or people generally, usually figure out information about the past?" (page 67). After this is a list of idealized student answers. However, only asking a version of the same question that students already struggled to answer may not effectively support all students.
- Lesson 2: An *Attending to Equity* margin note in Section 4 suggests allowing students to self-select reading based on interest or for students to choose which text to read based on difficulty (page 68). It also states that the teacher, "can read more about the text adaptations and text-specific suggestions in *UDL for Jigsaw Readings*."
- Lesson 3: An *Alternative Activity* box suggests using the Coherent Reading Protocol for students who would benefit from additional reading comprehension (page 96).
- Lesson 4: An *Additional Guidance* box suggests ways to support students with mathematical conversions and area calculations (page 110).
- Lesson 5: Students use a KWL Chart to record their thoughts while reading the *Light and Materials* text (page 153). An *Attending to Equity* margin note states that the KWL chart "structures the reading to provide support for emerging multilingual students and students with learning disabilities. However, this particular scaffold benefits all students by priming them to consider their relevant experiences before reading as well as helping them to identify a purpose for the reading."
- Lesson 5: An *Attending to Equity* margin note suggests how to support emergent multilingual students to understand the world "albedo" (page 153).
- Lesson 7: An *Attending to Equity* margin note suggests highlighting similarities in cognates to help support multilingual students (page 167).
- Lesson 9: An *Attending to Equity* margin note has grouping suggestions to help support multilingual students (page 203).
- The *Assessment Opportunities* boxes that are found in each lesson provide some strategies the teacher can use to help struggling students (see evidence in III.B). For example, in Lesson 4 the box states, "If students struggle to explain why sea ice does not affect sea level rise, show students another example setup of sea ice in a cup, this time measuring the water level both before and after the ice is placed in the container. Students will notice that the water level rose when the ice was added. Encourage them to consider what this means for the ocean–that sea ice is already affecting sea levels, so melting of the ice does not" (page 120).
- Varied teaching strategies for three-dimensional learning, such as ways to help struggling students integrate a CCC lens with the other two dimensions, are not specifically provided.

Extension opportunities are provided in the module. These opportunities are found in the *Alternate Activity* boxes and primarily focus on deepening DCI or SEP understanding. Some examples include:

- Lesson 1: An *Alternate Activity* box in Section 4 states, *"*Ask students to reflect back on why people, including their own ancestors, have migrated in the past. How were these experiences similar to or different from those of climate migrants? How might climate migration cause there to be different patterns of where people live than we see today? You may additionally assign students to read https://ensia.com/features/climate-change-nonnative-invasive-species/ as home learning and begin the next class with a discussion of whether people should label non-human animals and other organisms that have moved or spread because of climate change as 'invasive'" (page 41). This could help deepen DCI understanding.
- Lesson 2: An *Alternate Activity* box in Section 9 states "if students are particularly curious about historical data, give them 15–20 minutes to analyze geological and historical data from your own region. Then discuss these prompts…" (page 71). This could help deepen DCI understanding.
- Lesson 6: An *Alternate Activity* box in Section 12 states *"*Extension opportunity: Because of the many dark surfaces used in cities, many solutions have been proposed to change cities to increase their albedo (and the "urban heat island" effect that comes with a low albedo). Consider having students research these solutions, including "green roofs" and painting more urban surfaces white. This can also be an opportunity for contextualized practice of unit conversions. Specify an amount of paint required to cover a square foot and give information about the average square footage of roofs in your community. Have students set up their own conversion factors and calculate the amount of paint required to cover the roofs in a block or small area, your community, or the country" (page 161). This could help deepen some DCI understanding.
- Lesson 9: An *Alternate Activity* box in Section 2 suggests establishing an explicit temperature-volume relationship (page 197). This could help deepen some DCI understanding.
- Lesson 13: An *Alternate Activity* box in Section 2 suggests having students return to the climate models they saw in the unit and to explore them in more depth, paying particular attention to questions such as: *"*How are the models similar? How are they different? Are the differences only surface-level, or are they based on different data, mathematical models, and assumptions? Do any of these tools give access to multiple different sets of climate models or assumptions?" (page 282). This could help deepen some SEP and CCC understanding.

Suggestions for Improvement

- Consider identifying the strategies used for differentiated instruction.
- Consider increasing the percentage of student support strategies that go beyond repeating, rephrasing, or asking students to think more.
- Consider providing individualized learning strategies that help support students in three-dimensional learning.

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

Supports teachers in facilitating coherent student learning experiences over time by:

i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.).

ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions.

Rating for Criterion II.F. Teacher Support for Unit Coherence	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials support teachers in facilitating coherent student learning experiences over time. Strategies are provided to teachers so they can support students in making connections across lessons. However, the strategies and guidance do not often support students to see how their learning in the three dimensions is linked to sense-making.

Guidance is provided to teachers to support linking student engagement across lessons. Several tools are used in the unit to support teachers in facilitating coherent learning experiences. Some examples include:

- Lessons begin and end with a Navigation section that helps the students make connections to what they learned previously and what they will focus on in the next lesson.
- Lesson 1: In Section 1, the teacher is told to record student ideas and questions. The teacher is told "It is not necessary to have an exhaustive list at this point, but do keep the discussion going until you have the following ideas on the list (which will be helpful in the next activities and used again on day 3 for the Driving Question Board)" (page 36).
- Lesson 1: In Section 9, the teacher facilitates a discussion during which the class develops an initial consensus model (page 48). The *Key Ideas* box provides guidance about the goals of the discussion and what ideas the teacher should be listening for.
- Lesson 1: In Section 11, the materials provide guidance for creating the Driving Question Board (page 53). Guidance for how to elicit student questions, organize them, and sample student questions are provided. The teacher is instructed to, "Propose that these questions are all related to an overarching question, such as, "How can we slow the flow of energy on Earth to protect vulnerable coastal communities?" Title the DQB with this question or a similar one as phrased by your students" (page 54). The teacher is also explicitly guided for when to return to the DQB in future lessons so that students can see which questions they have answered and to add additional questions.
- Lesson 1: In Section 12, students generate ideas for investigations they could design to help them figure out the answers to their questions (page 54). An *Additional Guidance* box states that the list of ideas can be revisited throughout the unit (page 55). The teacher is told to point out when a future lesson involves an investigation like the one the class has suggested.

However, reminders are not included to help ensure the teacher will revisit them in future lessons.

- Lesson 9: The Navigation Section at the beginning of the lesson states "Let's recall what we learned about the Ilulissat Glacier and the proposed design solution for that site" (page 195). It is unclear if students are supposed to openly recall what they have learned, or if the teacher is simply stating that before moving on to some provided questions. If the former is the case, the materials do not explicitly list what should be recalled, which may make it difficult for a teacher to know how to link Lesson 9 to a previous lesson.
- Some of *Where We Are Going* sections at the beginning of each lesson help provide the teacher with some links to previous or future learning. For example, Lesson 8 states, "This lesson follows from the DQB check-in at the end of Lesson 7, where students realize that although they have answered many questions about surface melt, many more questions remain about potential melt being driven from below the glacier. Whereas in earlier lessons students asked questions, arising from models and unexpected results, that were possible to investigate with available materials in a laboratory setting, in this lesson students ask questions that must be answered by gathering evidence from the field" (page 176).

Throughout the unit some strategies and tools are provided that allow students to recognize what they have learned and what still needs to be figured out However, the strategies and guidance do not often support students to see how their learning in all three dimensions is linked to sense-making. Some examples include:

- The materials help guide the teacher as to when the students should set up and revisit their Progress Tracker. This helps students keep track of the DCI understanding they are building, but students are not supported in understanding how the topics link together to help them explain coastal towns having to move due to sea level changes.
- In Lesson 4, the teacher creates an anchor chart titled, "Strategies and Tools for Developing Mathematical and Computational Models" (page 114). The teacher adds different strategies and tools that students used in the lesson related to mathematics, and this chart is referred to as the Mathematical Anchor Chart in the unit. Student ideas that contribute to the chart include "we can estimate area using simple shapes and areas formulas," "scientific notation allows us to represent big numbers," and "we can convert between different units using conversion factors." The teacher is guided to return to, use, or update the chart in later lessons. The chart is often used to help students engage with mathematical work (i.e., Lesson 6, page 160). The chart can help students see how their understanding of mathematics is progressing through the unit. However, it is not clear if students will be able to use the chart to see how their use of SEPs is linked to sense-making.
- There are multiple references in the unit about an "Energy Anchor Chart" and a "Rules for Energy Transfer Anchor Chart." Page 13 states that "In Lesson 2, the class begins to formally develop energy transfer models, as described in *Energy Anchor Chart* (which also details how the "Rules for Energy Transfer" anchor chart is used to track student thinking). Sufficient teacher guidance is not provided for how to explicitly differentiate between the charts, as at some points it seems as if their names are used interchangeably. Based on the teacher prompts to add

to this chart, the chart(s) seem to be a place where the teacher records rules that the class uses to draw energy transfer models. It is not clear that this chart will explicitly help students link grade-appropriate CCC development to their progress in sense-making.

- In the Lesson 4 Exit Ticket, students are asked "How did using mathematical thinking about unit conversions help you make sense of polar ice melt and sea level rise?" and "How did thinking about scale and quantity help you make sense of polar ice melt and sea level rise?"

Suggestions for Improvement

Consider finding places in the unit where students could be supported to see how all three dimensions working together are helping them make progress in answering the unit question. Consider pointing out these opportunities to teachers.

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME	
Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.	
Rating for Criterion II.G. Scaffolded Differentiation Over Time	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials support teachers in helping students engage in the practices as needed and gradually adjust supports over time because although students engage with some SEP elements several times in the unit, there is no explicit guidance to help teachers know how and when to remove scaffolded support toward individual performance.

Students engage with elements of **Developing and Using Models** several times in the unit. Some reduction in scaffolding is evident in student expectations.

- *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
    - Lesson 1: In Section 6, Question 3 in the *Initial Model* handout prompts students to include "different components (parts), including ocean water; lines, arrows, or other symbols to show relationships between different components; a key that shows what any colors or symbols mean." Students develop a model to illustrate relationships between components of a system; however, the idea of systems is not made explicit. At this point, students do not use evidence in their model.
    - Lesson 3: This element is claimed. In Section 9, students work as a class to develop a model of energy flow in their investigation system (page 93). Students are asked

questions about the energy flow and are asked "what evidence do we have for that?" (page 94). Students work as a class to develop a model based on evidence to illustrate the relationships between components of their investigation system in terms of energy. This lesson therefore progresses students' proficiency in using the SEP element.

- Lesson 6: This element is not claimed, but in Section 7, students revise their models from Lesson 5 about how the microbead solution helps slow polar ice melt (pages 155). Students revise a model based on evidence from the investigation and reading to illustrate the relationships between components of a system. In Section 9, students use the model to make a prediction about what might happen to polar ice in the future (page 157). This lesson therefore allows students to practice the use of evidence, but without the scaffolding provided in Lesson 3. Note, however, that this SEP is not part of the key, claimed learning for this lesson.

Students engage with **Planning and Carrying Out Investigations** elements several times in the unit, but scaffolding is not changed much as the unit progresses. Some examples are:

- In Lesson 3 Section 3, students create an Investigation Anchor Chart (page 86). Although this states that students have engaged with **Planning and Carrying Out Investigations** in a previous high school unit, in Lesson 3, Section 4, the teacher is told to "introduce the concept of a scientific investigation question" (page 86). Students should already have an understanding of what an investigation question is, from the previous unit and from previous grade-bands. In Section 4, the teacher is also told to "pause to define the three variables and write the definitions on the anchor chart."
- *Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.*
  - In the four opportunities that students have to engage with this element, students do not get to actually plan an investigation.
  - Lesson 3: The investigation plan is provided in a handout. It is not developed collaboratively or individually. Students are told to read through the procedure and identify "what will change, what will be measured, and what will be kept the same in the investigation." Students then discuss how often they will take measurements.
  - Lesson 4: There is no prompt to develop a plan, especially not individually. A handout provides the procedure and students work in groups to build a data table and sketch a diagram of the lab set up.
  - Lesson 6: Students are still given the investigation plan. They identify the variables "that need to be considered, changed, and controlled" and "how do we make sure these variables are controlled?" but have a similar amount of scaffolding as in Lesson 3.
- *Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.*

- Lesson 6: Students are given the investigation design for the light investigation, and they identify the variables "that need to be considered, changed, and controlled." Students set up data tables based on the independent and dependent variables and then collaboratively conduct the investigation to produce data about how substances of different properties heat up differently when placed under a heat lamp. Students most likely use pieces of a Grade 6–8 element at this point.
- Lesson 10: The teacher provides students with the materials they will have for the investigation and the class discusses how each piece can be used. The class discusses the benefits vs. drawbacks of carrying out one trial for many conditions or many trials for fewer conditions. In Section 3, students work first independently and then collaboratively in groups to outline their procedures for three different testing conditions and to create the data tables they will need. A class data table is provided to students in an Excel spreadsheet format. Students begin building toward and engaging with pieces of this element for the first time during this lesson.

- *Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.*
  - Lesson 3: In Section 5, students use the sentence stem provided to complete creating a hypothesis for the carbon dioxide investigation (page 88). The sentence stem is "if the amount of carbon dioxide in the system increases, then the temperature of the system will…." Students are heavily scaffolded in making a directional hypothesis.
  - Lesson 11: In Section 3, students finish the directional hypothesis statement in the *Water-Ice Investigation Procedure* handout (page 259). Students are provided with the sentence stem "When heat from the warm water increases, the mass of the ice that melts will…" to complete the hypothesis. Students are still heavily scaffolded in making a directional hypothesis.

Students engage with an element of **Using Mathematics and Computational Thinking** during the unit.

- *Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).*
  - Lesson 4: In the unit conversions homework, students learn about and practice unit conversions with compound units. This skill is applied to the calculations required in the Sea Level Calculations worksheet. This worksheet requires students to use and make sense of ratios, percentages and unit conversions.
  - Lesson 4: In the Polar Ice Exit Ticket Key, students are expected to use this element, and the teacher is told "This aspect of Using Mathematics and Computational Thinking returns in Lessons 6 and 12" (page 2). Note that a different element of this SEP category is claimed in Lesson 6, rather than the same element claimed and used in Lessons 4 and 12.
  - Lesson 12: Students complete a worksheet with guided calculation tasks involving compound unit conversions in order to determine the amount of heat blocked by the

proposed berm. There is no difference in the level of scaffolding and independence expected of students compared to Lesson 4.

Suggestions for Improvement

- Consider reducing scaffolding for student use of all focal SEP elements over time as the unit progresses. For example, parts of the element could be explicitly learned and practiced during the unit, or the class could do the SEP element together early on and students could be expected to use it with less scaffolding in later lessons.
- Consider using the Investigation Anchor Chart to help students build proficiency in the targeted grade-appropriate SEP elements for **Planning and Carrying out Investigations**. Using the chart to provide students with scaffolding that is gradually reduced for each investigation could help make students increasingly more responsible each time they engage with the elements.

OVERALL CATEGORY II SCORE: 3 (0, 1, 2, 3)	
Unit Scoring Guide – Category II	
Criteria A-G	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

CATEGORY III

MONITORING NGSS STUDENT PROGRESS

III.A. MONITORING 3D STUDENT PERFORMANCES

III.B. FORMATIVE

III.C. SCORING GUIDANCE

III.D. UNBIASED TASK/ITEMS

III.E. COHERENT ASSESSMENT SYSTEM

III.F. OPPORTUNITY TO LEARN

III.A. MONITORING 3D STUDENT PERFORMANCES

Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.

Rating for Criterion III.A. Monitoring 3D Student Performances	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials elicit direct, observable evidence of students using practices with core ideas and crosscutting concepts to make sense of phenomena or design solutions. There is a match between most learning goals and elements assessed in the unit as well as the elements intended to be assessed and those assessed for all three dimensions.

Related evidence includes:

- The *Assessment Section Overview* states that "The structure of *every* lesson-level-performance-expectation (LLPE) is designed to be a three-dimensional learning [sic], combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts" (page 292). For example, under the LLPE column, for Lesson 1, the following color-coded claim is made, "1.A Ask questions that arise from examining models to clarify and seek additional information about changes and rates of change in sea levels and the resulting impact on human migration. (SEP: 1.2; CCC: 7.2; DCI: ESS3.B.1)." Then under assessment guidance, suggestions for when and what to look for are given. However, the connection between the color-coded LLPE opportunities and the artifacts students produce is sometimes unclear. The stated observable evidence often does not always clearly relate to evidence of students engaging in the targeted elements of the three dimensions.
- The *Assessment System Overview* (page 288) identifies artifacts produced in each lesson that can be used for assessment. These artifacts include initial models, Driving Question Board, Exit Tickets, data analysis, investigations, multiple guided worksheets, and discussion mapping tool. Individual artifacts include:
  - Lesson 2: In one of the Assessment Opportunities, the teacher is told "You should collect Data Analysis to better understand the thinking of students who do not share in the oral argumentation. This is an important moment to gather evidence of students' argument-based evidence, using pieces of disciplinary core ideas from their readings, with Stability and Change as a lens" (page 72).
  - Lesson 4 Section 14: In the Assessment Opportunity, the teacher is told "This discussion provides an opportunity to gain initial evidence for students' three-dimensional thinking. They use a mathematical tool like unit conversions, along with Scale, Proportion, and Quantity thinking, to track increasingly nuanced understandings of how humans are impacted by natural hazards. Push to ensure that all three elements are present and used together, as students must use multiple dimensions together,

particularly unit conversions, in the individual exit ticket at the end of the lesson" (page 123).

- Lesson 12 Section 3: In the Assessment Opportunity, the teacher is told "This three-dimensional assessment opportunity is a chance for students to use mathematical, particle, and system models together to track energy and matter flows as part of understanding humans' ability to manage their impacts (in this case, specifically how the berm affects this ability). Even after consensus modeling, it is useful to collect students' individual models to provide feedback on the use of all three dimensions together, as well as individual elements of the dimensions" (page 269).

- Students have opportunities to engage with high school levels of the targeted SEP, CCC, and DCI elements together in multi-dimensional assessment throughout the unit. However, there is occasionally not a match between the elements claimed as assessment targets and the elements students use in the tasks. Related evidence includes:
  - Lesson 3: Students are asked to develop investigation questions, but this artifact is labeled as a student performance of SEP 3.1, which is partially claimed in the beginning of the unit as: *Plan an investigation ~~or test a design individually and~~ collaboratively to produce data to serve as the basis for evidence as part of ~~building and~~ revising models, ~~supporting explanations for phenomena, or testing solutions to problems~~. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled*. The teacher is told to look/listen for: Students develop an investigation question that is able to test the relationship between the amount of carbon dioxide present and increased temperature (SEP: 3.1; DCI: ESS2.D.3)" (page 86). However, students would need to use very little of the partially claimed SEP element in order to develop the investigation question.
  - Lessons 4 and 9 have Exit Tickets that are identified as assessment points. The Lesson 4 Exit Ticket task focuses on calculating the amount of ice on Greenland and ultimately the resulting sea level rise, which helps ground the task in a real-world phenomenon. In the Exit Ticket, there is reference to element-specific artifacts and the evaluation of the learning associated with that element. The short answer portions of Questions 1 and 2 have the potential of providing evidence to monitor students' multi-dimensional thinking.
  - In Lesson 7, the *Thawing Permafrost* is identified as an assessment task. Students are shown a video of thawing permafrost and given a table of some of the effects of the thawing permafrost. This scenario sets up a phenomenon that students try to make sense of. Some questions require students to use two grade-appropriate dimensions in their answer. For example, Question 1c asks students, "Are the feedback loop(s) that affect(s) permafrost positive feedback loops or negative feedback loops? Explain your thinking using words and/or pictures and connect your response to the specific changes in Earth systems that are described in the diagram.."
  - In Lesson 13, the *Heat Pump Transfer Task* is identified as an assessment task. Students read a scenario about heating and cooling. This scenario sets up a real-world context of people needing to address indoor cooling/heating units as temperatures rise. The

identified assessment targets for each question mostly match the elements that students are required to use to respond to the question.

Suggestions for Improvement

- Narrowing the list of targeted learning and assessment targets could help provide students with more opportunities to show their progressive understanding of the targeted learning.

III.B. FORMATIVE

Embeds formative assessment processes throughout that evaluate student learning to inform instruction.

Rating for Criterion III.B. Formative	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials embed formative assessment processes throughout that evaluate student learning and inform instruction. Many formative assessment opportunities are identified throughout the unit, and most of these opportunities provide guidance as to what the teacher should look for in student answers and how they can modify instruction. However, there are few examples of varied student responses (and what to do about each level of response), and there is not clear support for responding to different levels of student thinking across all three dimensions (in contrast to listing the existence of dimensions).

The materials identify many formative assessment opportunities throughout the unit. Many of these opportunities are identified in *Assessment Opportunity* boxes that are embedded throughout the lessons and that are also included in the *Assessment Overview System* (page 288). The *Assessment Opportunity* boxes suggest to teachers what to look/listen for and what to do. The "what to look/listen for" guidance could be interpreted as performance markers used in evaluating student performance. The "What to do" guidance could be interpreted as suggested teacher actions that are a response to student performance that does not match the performance markers above. However, there is often no explicit guidance for these formative assessments that would help teachers make targeted instructional adjustments.

Related evidence includes:

- The unit provides an overview of the assessment opportunities in the *Assessment System Overview* (page 288). This overview has two sections entitled: 1) Overall Unit Assessment, and 2) Lesson-by-Lesson Assessments.

- The overall unit assessment section has a broad focus and includes narrative commentary on a variety of assessment types (driving question board, model generation and revision, exit tickets, investigation analysis, guided calculation help, and other guided worksheets). These assessments offer a variety of ways for students to demonstrate thinking (writing, discussion, drawing, and calculation). The narrative for explicitly called out formative assessments frequently list what students do, and sometimes tell teachers what to look for regarding monitoring growth. However, they rarely help the teacher know what to do next, especially in relation to supporting CCC understanding, and do not provide clear guidance related to different levels of student responses. For example, in Lesson 6, the narrative says, "Students complete the most independent energy transfer models here that they have to date. Collecting these handouts after the lesson would also allow the teacher to see if students modified their models to include the "reradiation arrow" from CO_2 back to the surface, which indicates that a feedback loop is occurring (page 289)." The student artifact is clearly described. This allows the teacher to know what to assess. This particular assessment guidance tells teacher what to look for to potentially pinpoint growth (reradiation arrow). However, there are no explicit teacher moves associated with what next steps to take based on varying student needs.
- The Lesson-by-Lesson Assessment section repeats the explicitly labeled formative assessments that occur in each lesson. There are 29 clearly labeled formative assessment opportunities throughout the unit. Each of these formative assessments presents information in a color-coded format, referring to the three dimensions the opportunity is meant to assess. For example, in Lesson 5, the following look/listen for is listed in the table:

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 5	**5.A** Ask questions to refine a model of the energy transfer into, out of, and within the system if proposed solutions prevent glacier ice melt in Disko Bay. (SEP: 1.4; CCC: 4.1; DCI: PS3.B.2) **5.B** Use energy transfer consensus models to ask questions that challenge the suitability of the design solutions based on their current and future impacts. (SEP: 1.7; CCC: 4.3; DCI: ESS3.D.1)	**5.A When to check for understanding** On day 2 when students go public with their ideas and ask questions to refine the class consensus model (**slide R**). **What to look/listen for during the opportunity:** • Questions seek to clarify or refine a portion of their model. (SEP: 1.4) • Questions seek to refine how energy moves into the system. (SEP: 1.4; DCI: PS3.B.2) • Questions seek to refine where energy is moving from one place to another. (SEP: 1.4; DCI: PS3.B2) • Wonder how energy would move within the system without any proposed solution. (DCI: PS3.B2: CCC: 4.1) • Wonder how energy would move within the system if the proposed solution prevents ice melt. (DCI: PS3.B2; CCC 4.1) • Wonder about specific design features of the proposed solutions. (CCC: 4.1) **5.B When to check for understanding** On day 2 when students are writing their new questions for the DQB (**slide T**). **What to look/listen for during the opportunity:** • Questions challenge the suitability of the proposed design. (SEP: 1.7) • Questions grapple with predicting and managing current and future impacts of the design solution. (SEP: 1.7; DCI: ESS3.D.1) • Questions inspired by the class consensus model that simulates energy flows within and between systems. (SEP: 1.7; CCC: 4.3) • Wonder about the magnitude of human impacts in consideration of these design solutions. (DCI: ESS3.D.1)

However, the description of what to look for in student work is often not clearly defined enough to allow teachers to identify the expected learning artifact. For example, in the screen shot above, teachers are told to look for students wondering how energy would move within a system.

- *Assessment Opportunity* boxes are found throughout the unit. These boxes identify at point in the lesson the teacher can stop to assess student progress, what the teacher should look/listen for, what the teacher can do as the next instructional steps, and what LLPE students are building toward. The LLPE and what to look/listen for information is color coded to connect to the three dimensions, and element codes for each dimension are identified as the intended assessment targets. While most of these assessment opportunities claim to be multi-dimensional, there is not always observable evidence in the assessment prompts that students will engage with the elements that are claimed. The instructional guidance also often does not include support for modifying instruction if students are struggling with one of the three dimensions in particular. For example:

- Lesson 1: "What to do:….Collect these models if you do not have time to look at them in the lesson and use them to gauge how students are using models to show three-dimensional thinking; that is, that they are able to model changes in matter and energy to explain the mechanisms behind and impacts of natural hazards like sea level rise. Feedback around these dimensions can also help support student thinking as they begin to use energy transfer models in subsequent lessons" (page 44).
- Lesson 2: In Section 11 the following assessment opportunity is identified. The 'what to look/listen for' section lists elements from all three dimensions, but the "what to do" section only provides guidance for what to do if students struggle to identify questions. It does not provide guidance for what to do if students struggle with the CCC or DCI elements. There is also no observable evidence that students would ask questions that show an understanding of CCC 7.2 or ESS3.B.1.

  "What to look/listen for in the moment:
  Questions consider why changes in sea level rise are occurring and whether they can be prevented or reversed. (SEP: 1.2; CCC: 7.2)
  Questions consider how sea level rise is impacting human migration. (SEP: 1.2; DCI: ESS3.B.1) Questions should seek to clarify confusing portions of their models. (SEP: 1.2)
  What to do: If students struggle to identify questions, encourage them to revisit their notes from the lesson and the initial consensus model. You may also elicit from students what they have done in the lesson so far in order to refresh their memories about parts that may have been more or less clear.
  Building toward: 1.A.3 Ask questions that arise from examining models to clarify and seek additional information about changes and rates of change in sea levels and the resulting impact on human migration. (SEP: 1.2; CCC: 7.2; DCI: ESS3.B.1)"

- Lesson 2 Section 13: In the Assessment Opportunity, the teacher is told to "Collect notebooks to examine models more closely if needed, and provide students feedback around their use of all three dimensions together as well as specifically around the energy transfer models. This will support student use of energy transfer models in subsequent lessons" (page 76).
- Lesson 2: In Section 14, students set up their Progress Trackers and the *Additional Guidance* box states that "The sample Progress Tracker included in these materials serves as teacher guidance for what students may say at various points throughout the unit. Some students may say more, others may say less. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment. In this way, the Progress Tracker can be used to formatively assess individual student progress throughout the unit" (pages 77–78). Guidance for

what to look for to monitor student progress or how to modify instruction accordingly is not provided.

- The Lesson 4 Exit Ticket (page 124) and the Lesson 9 Exit Ticket provide suggested instructional modifications. The Exit Tickets include "what to do" sections that are color coded (in reference to the dimensions) about what the teacher can review or return to (it is assumed if students incorrectly answered the question). For example, Question 1 in the Lesson 9 Exit Ticket includes a "What to do" section that states "Have students review their slope calculations and reflect on how we connected the slope to density. Ask, "How much would the mass of one liquid INCREASE for every mililiter of liquid added – by 1.8 g or 0.543 g?"
- Lesson 5 Section 10: In the Assessment Opportunity, the teacher is told "In addition, the questions students ask in this question should be three-dimensional: focused on the suitability of the proposed designs, concerned with managing impacts, and with a Systems lens that emphasizes interactions between potentially disparate components. If students' questions are not three-dimensional, you encourage them to re-write them as such or develop new questions that are. This feedback will be beneficial as students are responsible for asking three-dimensional questions in the assessment task in Lesson 7.
- Lesson 8 Section 3: In the Assessment Opportunity, the teacher is told to "This three-dimensional assessment moment is important because of its emphasis on systems. You may wish to follow up with individual students to provide feedback on system definition, as this idea will play a key role in future lessons, including the transfer task. Also use this opportunity to identify evidence that students are using all three dimensions together in discussion" (page 185).
- Lesson 9: In Section 3, students are given three questions and are asked "which of these questions would be the most testable and relevant to what we want to figure out? Why?" (page 199). The teacher guide then says to "Listen for these ideas (from students): Even though we care about (A), it is not really testable. (B) does not fully relate to or describe what we want to figure out. (C) is something we can test and it describes the specific question we want to clarify– why warm saltwater behaves differently than we expect based on its energy." However, the teacher guide does not provide guidance to teachers on what to do if the ideas of testable and relevant questions do not show up in student responses.
- Lesson 10*:* A teacher sidebar note says: "Students are bringing to table practical knowledge of the computational model they are using, along with observations of the particles. If it is unclear from student responses, follow up by asking, If the temperature is the same, how is the energy spread or distributed? Use the simulation to show that it is spread evenly. Use examples like cooling coffee and refrigerators to highlight that this spread happens in uncontrolled systems, but not in controlled systems" (page 240).
- There are over 40 margin notes entitled Attending to Equity. However, these are not specifically tied to or referred to in the explicitly called out formative assessments.

Suggestions for Improvement

- Consider more often providing teacher response strategies for different levels of student performance related to each of the three dimensions.
- Consider providing formative assessment supports that go beyond just getting kids to provide the right answer, to moving toward and connecting to the next part of the lesson.

III.C. SCORING GUIDANCE

Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.

Rating for Criterion III.C. Scoring Guidance	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials include aligned rubrics and scoring guidelines that help the teacher interpret student performance for all three dimensions. Sample student responses are included for many smaller tasks throughout the unit, and several scoring guides are included that identify assessment targets and exemplar student responses. However, some of the claims and guidance do not match up with the observable evidence of actual student performance, and students are not supported to track their own progress in all three dimensions.

Related evidence includes:

- Sample student responses are provided for the Suggested Discussion prompts in each lesson.
- Answer keys are included for many of the handouts that students work through in the unit.
- In the Assessment Opportunities throughout the unit, codes for assessment targets are given, but no indications are given when only parts of the elements claimed in the unit are targeted for a given assessment. In these cases, teachers would need to identify their own assessment targets. For example, in Lesson 3, students are asked to develop investigation questions, but this artifact is labeled as a student performance of SEP 3.1, which is partially claimed in the beginning of the unit as: *Plan an investigation ~~or test a design individually and~~ collaboratively to produce data to serve as the basis for evidence as part of ~~building and~~ revising models, ~~supporting explanations for phenomena, or testing solutions to problems~~. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled*. The teacher is told to look/listen for: Students develop an investigation question that is able to test the relationship between the amount of carbon dioxide present and increased temperature (SEP: 3.1; DCI: ESS2.D.3)" (page 86). The assessment target is therefore listed as

SEP 3.1, but students would need to use very little of this element in order to develop the investigation question.

- The Exit Tickets in Lesson 4 and 9 have a scoring guide. The scoring guides identify the target SEP, DCI, or CCC element that each question assesses and provide correct responses rationale for distractors. For example:
    - In the Lesson 4 Exit Ticket, the scoring guidance shows that there is an element from each dimension as an assessment target for Question 2. The Lesson 4 Exit Ticket scoring guide (page 335) shows the prompts and correct student answers. In the color-coded table in the answer key, this assessment claims to use two elements. Short answer prompts provide potential assessment evidence for two-dimensional performances.

      4.A Apply ratios and unit conversions at different scales to make predictions about the impact of human-caused ice melt on sea levels and human populations. (SEP: 5.5; CCC: 3.1; DCI: ESS3.B.1, ESS3.D.1)
- A rubric is provided for the *Thawing Permafrost* Assessment (page 349).
    - Exemplary student responses are provided.
    - A Scoring Guidance section states that "In some cases different elements of the response are identified with a separate + symbol. These + 's are not meant to be all inclusive; they are suggestions for what you may see your students include." The guidance continues to explain the presence of the symbols and how to use them.
- A rubric is provided for the *Heat Pumps Transfer Task.*
    - Assessment targets are identified at the element level for each question under a table column titled "3D Elements Addressed in this assessment." A PE is also identified at the top of the rubric, which seems to imply an assessment target as well.
    - Exemplary student responses are provided for most questions, along with a rubric for question 6.
    - A Scoring Guidance section states that "In some cases different elements of the response are identified with a separate + symbol. These + 's are not meant to be all inclusive; they are suggestions for what you may see your students include." The guidance continues to explain the presence of the symbols.

Suggestions for Improvement

- Consider including more often in the materials example student responses related to different levels of student performance related to each of the three dimensions for each formative assessment task. This could be in addition to the look fors that relate to the different dimensions.
- Consider modifying the scoring guides so that they consistently and accurately reflect the elements students are required to use for each question in the tasks.
- Consider clarifying whether full elements are assessment targets when they are coded in the LLPEs, or whether only a small piece of an element is intended to be used in the assessment.
- Consider including ways to help students to track their own progress toward the unit's learning goals. This could include helping students know what to aim for and possible ways to adjust.

III.D. UNBIASED TASK/ITEMS

Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.

Rating for Criterion III.D. Unbiased Task/Items	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials assess student proficiency using accessible and unbiased methods, vocabulary, representations, and examples because there are some situations in which prompts are communicated in multiple modalities and some on ramping is provided to help students adjust to scenarios that are unfamiliar. However, assessment expectations are mostly language-based.

Related evidence includes:

- The representations and scenarios used in the lessons are generally unbiased and fair. For example, the unit makes an effort to support students in understanding the different names they may encounter for some glaciers they are studying (Danish vs. indigenous).
- The vocabulary used is grade level appropriate.
- In Lesson 1, page 52, students choose "… a community agreement they will focus on." Later on, page 54, students make another choice as shown by, "Choose one question or category of questions from our Driving Question Board and talk with a partner or partners near you to consider how we might find the answer—what investigation could we design, what data should we gather, and how could we figure this out in our classroom?" In Lesson 2, page 68, there is another student choice as shown by, "… students can choose which text to read based on difficulty." However, these choices are not associated with modalities of responses.
- Student tasks and readings include maps, graphs, images, and data tables.
- Lesson 1: While students discuss questions, an *Attending to Equity* box states "Universal Design for Learning: Reinforce that students have multiple options for expressing their ideas. Encourage the use of gestures, drawings, and physical representations, especially as students describe their ideas about where water is on Earth and how water levels rise in different situations. Use the language(s) and terminology your students use to describe and explain their ideas, especially during this first lesson. There will be appropriate points later in the unit to name specific vocabulary" (page 42).
- In Lesson 13, the Heat Pump Transfer Task (summative assessment) may be biased for some students.

- There are four graphs and four photos associated with the reading, representing a modality other than language through which students can gather information. The Heat Pumps Rubric tells the teacher that "Students can respond to questions on this assessment in writing, using illustrations, gestures, and languages other than English" (page 1). Note that this same guidance is not given to students, either on the student version of the task or in the teacher guide.
- The reading level of the text in the Heat Pump Transfer Task may be above grade level. This could bias assessment results against students with low reading skills. The possible higher reading level of the text is not explicitly mentioned. On page 286, the heat pump individual summative assessment has this "Attending to Equity" margin note associated with it: "The scenario associated with the transfer task may be intimidating for some students due to the reading involved. It is recommended you read this scenario as a class before engaging in the transfer task, printing it off on a separate handout for students if desired. Alternatively, give students an opportunity to read the scenario individually or with a partner, then have a few students summarize what they learned from the scenario."

Suggestions for Improvement

Consider more often allowing students the option to use different modalities to respond to assessment prompts. Consider also including teacher support in the form of students' answers for each modality.

III.E. COHERENT ASSESSMENT SYSTEM

Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.

Rating for Criterion III.E. Coherent Assessment System	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials include pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. All four assessment types are included in the unit.

The *Assessment System Overview* (pages 288–292) lists the different assessment opportunities and types found in each lesson. It identifies pre-assessment, self-assessment, formative assessment, and summative assessment opportunities in the unit.

- Each explicitly called out assessment (pre-post, formative, handouts, investigations, exit tickets) lists identified assessment targets. These targeted elements are identified by color-coded excerpts of the full element language and by codes. The number and frequency of claimed elements is appropriately distributed among SEPs, CCCs, and DCIs. However, sometimes there is not explicit evidence that students need to use the claimed elements in the task prompts as is claimed (see related evidence in III.A, III.B, and III.C). This results in some of the assessments not directly connecting to the learning goals as intended.
- A summary of each assessment is provided that focuses on what students do in the assessment. These summaries provide the teacher with basic information about the purpose of the assessment and some of them describe why student learning is measured. The lesson-by-lesson section repeats what each formative assessment opportunity says from within each lesson. This includes parsed phrasings of the claimed elements along with the NGSS numbering system references and some generic assessment guidance. The numbers and excerpted elements are clearly listed.
- Most task prompts require students to use grade-appropriate elements from two dimensions.

Pre-assessment

- Lesson 1: A pre-assessment opportunity is identified in the *Assessment Opportunity* box in Section 6 (page 45). The teacher is told "Because this is the first lesson in the unit, this is a pre-assessment opportunity to see where students are in the progression for the three dimensions targeted here. Collect these models if you do not have time to look at them in the lesson and use them to gauge how students are using models to show three-dimensional thinking; that is, that they are able to model changes in matter and energy to explain the mechanisms behind and impacts of natural hazards like sea level rise. Feedback." Assessment targets are identified as SEP 2.3, CCC 5.2, and DCI ESS3.B.1. Guidance for noticing some features of three-dimensional performance is provided, but no explicit measurement guidance for interpreting student responses or for modifying instruction accordingly is provided.

Self-assessment

- In the Overall Unit Assessment section (page 291), the materials discuss self-assessment and say, "The Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena. They help to figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Trackers reflects their own thinking at that particular moment in time. In this way, the Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Trackers are meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion." However, students do not have any criteria with which to assess their progress. The tracker also focuses on DCI-related learning and does not provide self-assessment insight related to SEP or CCC understanding.

- The Overall Unit Assessment section (page 292) states, "The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day." However, this self-reflection is unrelated to learning goals.
- The Lesson 4 Exit ticket asks students to "Describe how reasoning about scale, proportion, and quantity like this helps you understand the impacts of climate change on human populations, like migration" and "Briefly explain how calculations from the lesson supported your thinking about the scale of sea level rise and its impacts." These questions allow students an opportunity to reflect on their general SEP and CCC learning.
- The Lesson 9 Exit ticket asks students "Explain how finding the slope of the line of best fit helps you understand energy transfer in the water in a location like Disko Bay." This question allows students an opportunity to reflect on their SEP learning.

Formative assessment

- See related evidence under Criterion III.B

Summative Assessment

- In Lessons 4 and 9, the Exit Tickets are identified as either formative or summative assessments. Assessment targets are identified at the element level for each question, and the short response prompts provide opportunities for students to exhibit multi-dimensional performances.
- In Lesson 7, the Thawing Permafrost task is identified as either formative or summative assessment. Students are shown a video of thawing permafrost and are given a table of some of the effects of the thawing permafrost. This scenario sets up a phenomenon that students try to make sense of. Assessment targets are identified at the element level for each question. Some questions require students to use two dimensions in their answer. For example, Question 1e asks students, "Could thawing permafrost contribute to other feedback loops we have seen in this unit? If so, how would other Earth systems (spheres) be impacted? You may write your answer below or add it to the model." In this case, students need to show an understanding of pieces of CCC 7.3 and ESS2.A.1 to answer the question.
- In Lesson 12, the *Berm Model* and the *Calculating Berm Impact* handouts are identified as either formative or summative assessments. The *Berm Model* handout asks students to develop a model to answer the question, "how much does the berm solution impact energy flows and sea level?" Students use pieces of elements from all three dimensions (although not all of them are the ones claimed) to develop the model. The *Calculating Berm Impact* handout mostly asks students to complete calculations, which requires them to use SEP understanding. Question #7 in the handout requires students to use their calculations along with DCI understanding.
- In Lesson 13, the Heat Pump Transfer Task is identified as Summative Assessment. Students read a scenario about heating and cooling. This scenario sets up a real-world context of people needing to address indoor cooling/heating units as temperatures rise.

Suggestions for Improvement

- See evidence under Criterion III.B for how to strengthen the integration of formative assessment in the unit.
- Consider modifying the assessment targets so that they accurately reflect the elements students are required to use in the tasks. Alternately, consider modifying the assessment tasks so they require students to use the assessment targets for each one.

III.F. OPPORTUNITY TO LEARN

Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

Rating for Criterion III.F. Opportunity to Learn	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide multiple opportunities for students to demonstrate performance of practices connected with their understanding of core ideas and crosscutting concepts because students do not have multiple opportunities to demonstrate growth in understanding for all of the key claimed learning in the unit.

Students have few opportunities to iteratively engage with the same SEP element to demonstrate their growth in proficiency over time. One exception is for modeling. Students practice modeling collaboratively and independently during the unit. In Lesson 1, students receive feedback on their models (SEP 2.3, page 44). In Lesson 9, page 215 states "Turn and Talk. Display slide Y and ask students to take out Revisiting Questions and Revising Models from last class. Invite students to add to their models as they turn and talk with a partner." This is an opportunity for all students to receive feedback on their models. Students also receive feedback in Lesson 12 on their use of a different modeling element (page 269), and in Lesson 5, students receive feedback on their questions (SEP 1.7, page 142). However, these kinds of opportunities are not provided for all of the focal SEPs in the unit, and for several focal SEPs, students only use them one time in the unit.

Students have few opportunities to explicitly engage with the same CCC element that shows their growth in proficiency over time. In Lesson 8 Section 4, the *Revisiting Questions and Revising Models* handout gives students a model about how energy is currently moving in Earth's systems (page 183). Students are given two scenarios (from previous Lesson 5 and 6 models) and they revise the model for each scenario and write hypotheses of what is happening. Students show changes of energy flow into and within the Earth's system and changes in matter within the system so they engage with pieces of the claimed CCC element *5.2 Changes of energy and matter in a system can be described in terms of* *energy and matter flows into, out of, and within that system.* Students also receive feedback on this same CCC element use in Lesson 1 (page 44), Lesson 2 (page 76), and Lesson 12 (page 269). Students also receive feedback for two other CCC elements, but not for all of the focal CCC elements in the unit.

Students have opportunities to iteratively engage with the same DCI element such that they can demonstrate their growth in proficiency over time, and there are some feedback opportunities to help students develop their understanding. However, these opportunities are not provided for all focal DCIs. For example:

- The Progress Tracker may be able to show student growth in DCI understanding. Students begin working on the Progress Tracker in Lesson 2 and continue to add to it throughout the unit.
- In Lessons 3, 6, and 9, the following DCI is claimed: ESS2.D.1, *The foundation for Earth's global climate systems is the ~~electromagnetic~~ radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space*. This three-lesson sequence could be an opportunity for students to demonstrate performance regarding this DCI. Note that the crossed-out portions of this DCI are different in each lesson, making the learning goal different in each lesson. This could make it difficult for teachers to know the learning target since it changes from lesson to lesson. If teachers do not know the learning target, it could be difficult to establish the sort of iterative feedback that leads to preparation for the next assessment.
    - Lesson 3: This three-lesson sequence from which iterations might be observed starts with a formative assessment on page 95. This assessment comes after the teacher provides what is called an energy transfer model (sketch) of the carbon dioxide and water bottle investigation. Then the teacher provides an analogous model that replaces the heat lamps with the Sun, air above the water bottles with CO_2, and water with ice. Arrows still represent energy flow and dotted lines presumably represent the boundary of the water bottle system. Since the teacher provides this analogy sketch, it is difficult to know if students understand the important parts of comparison in the analogy. In the "What to do" section of the assessment, the instructions say to, "Encourage students to draw comparisons between the investigation and the real-world Earth system. Use the "Rules" to help establish how the energy source (Sun) varies between the models, but energy likely behaves in a similar way once in the system." The teacher guidance does not provide support for how to "encourage" or what to look for as concrete evidence that the targeted results of encouragement took place. There is no explicit mention of feedback and no communicated sense of an iterative process, especially one that potentially leads to doing better on the next assessment for this DCI.
    - Lesson 6, page 150, has another formative assessment that claims this DCI. Before this assessment, the materials have instructed the teacher to provide students with a prescribed procedure for an investigation to "… see how substances with different properties (white and black paper) heat up differently when placed under a heat lamp." Students follow the procedure and record temperature data. In the "What to do" part of the assessment, it says, "If students are unsure of how energy flows through the system, remind them of earlier lessons in the unit where we identified energy transfers through

light." There is no prompt for obtaining feedback and no instructions for students to use feedback to get ready for the next assessment.
    - Lesson 9 has a formative assessment that claims the same DCI. The assessment occurs after the teacher has used a long set of leading questions to explain what the teacher draws as a particle model of energy transfer among fresh, salt, cold, and warm water. The assessment once again uses the teacher instruction "encourage" to get students to demonstrate targeted learning goals. But there are no explicit instructions on how to do this, what to look for, or how to connect the outcomes to previous iterations.
- Students also receive feedback related to parts of five other DCI elements during the unit:
    - Lesson 1: Students receive feedback on DCI ESS3.B.1 (page 44).
    - Lesson 2: Students receive feedback on initial use of DCI: ESS1.B.2, ESS2.A.3, ESS2.D.2 (page 76).
    - Lesson 5: Students receive feedback on ESS3.D.1 (page 142).
    - Lesson 12: Students receive feedback on ESS3.D (page 269).

Suggestions for Improvement

- Consider establishing a feedback cycle at several points in the unit through which students can receive and respond to teacher feedback related to key learning goals in all three dimensions.
- Consider providing opportunities for students to show improved performance over time for all targeted elements of each of the three dimensions as a response to feedback they have received from their teachers or peers.
- Consider incorporating specific, concrete actions within iterative assessments involving targeted DCIs and CCCs that help teachers and students know how feedback helps students do better on the next assessment in the series.

OVERALL CATEGORY III SCORE: 3 (0, 1, 2, 3)	
Unit Scoring Guide – Category III	
Criteria A-F	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

SCORING GUIDES FOR EACH CATEGORY

OVERALL SCORING GUIDE

Scoring Guides for Each Category

Unit Scoring Guide – Category I (Criteria A-F)	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

Unit Scoring Guide – Category II (Criteria A-G)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

Unit Scoring Guide – Category III (Criteria A-F)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

OVERALL SCORING GUIDE	
E	**Example of high quality NGSS design—**High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9)
E/I	**Example of high quality NGSS design if Improved—**Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7)
R	**Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5)
N	**Not ready to review**—Not designed for the NGSS; does not meet criteria (total 0–2)