Structure and Properties of Matter

DEVELOPER: OpenSciEd

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

Structure and Properties of Matter

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 the Science Peer Review Panel using the EQuIP Rubric for Science.

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

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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 the use of a compelling, relatable anchoring phenomenon. The pursuit of sense-making of this phenomenon is a driving force for the continued learning throughout the unit, serving as a meaningful reason for the coherence of the unit. As a result, each lesson builds upon prior learning from the lesson before it and subsequent learning is initiated to address identified gaps in students' learning related to the central phenomenon.

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

- **Differentiated Instruction.** There are numerous opportunities for students to receive support for issues relating to reading skill, limited mathematical proficiency, and for emerging multilingual learners. The supports for each of these groups are meaningful and commendable. Despite those supports, clear ideas for supporting students with physical disabilities are not sufficiently addressed and teacher guidance for how to appropriately modify instructional tasks do not appear within the unit as currently constructed.
- **Progress Trackers**. The use of progress trackers serve as a means of student self-assessment and summaries of learning related to sense-making of the central phenomenon. Consider including additional emphasis on the progress tracker in later lessons as students continue to build upon their knowledge of the phenomenon. In this case, how issues such as lightning safety fit into their efforts to understand the nature of lightning and lightning strikes would serve as meaningful opportunities for students to synthesize understanding of the mechanics of the phenomenon to the implications of it in the natural world we all inhabit.
- **Crosscutting Concepts (CCCs).** Students are currently supported to develop and use several crosscutting concept elements during the unit. However, there is a significant mismatch in some of the targeted elements. Consider supporting students to use all of the claimed elements in the unit, or clarifying targets for elements that are not intended to be fully used.

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.

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that learning is driven by students making sense of phenomena or designing solutions to a problem because each lesson places the phenomenon of lightning strikes at the forefront of all conversation. Student questions, ideas, and investigative priorities continuously move the class forward through the unit and student sense-making is a key driver of this progress.

The materials are organized so that students are focused on figuring out a central phenomenon and lessons have the class regularly revisit the phenomenon throughout the unit. Related evidence includes:

- Lesson 1: As students discuss answers to questions about whether lightning is energy or matter, they are brought back to the phenomenon they are figuring out with the question, “How does answering these questions help us figure out what causes lightning?” (Teacher Edition, page 46).
- Lesson 3: Students brainstorm phenomena that are similar to the water dropper system. “What other phenomena have you experienced that produced interactions like those we observed in the water dropper system?—for example, attractive or repulsive forces at a distance, or small sparks or shocks” (Teacher Edition, page 89).
- Lesson 8: “Review what students have observed and figured out about static phenomena. Display slide C and instruct students to make a Notice and Wonder chart in their science notebooks. Say, we have seen that for objects to become charges, there needs to be some sort of contact with another object. Hold up an inflated balloon with a string tied to it and ask students what they expect to happen if you hold it near a wall” (Teacher Edition, page 177).
- Lesson 8: “Apply polarization to lightning. Say, we have figured out some pretty big ideas about atoms and charge and attraction. Let’s see if we can apply this idea to our lightning system” (Teacher Edition, page 184).
- Lesson 11: Students rewatch the videos of lightning strikes in slow motion from Lesson 1 and are asked “what did you notice that could help us figure out why or how the charges move between the cloud and ground?” and are eventually asked to reflect on the role that air plays in these scenarios (Teacher Edition, page 222).

- Lesson 12: “Last class we figured out a lot about how lightning moves through air and what changes are happening to the atoms and molecules in the air. But what questions do we still need to figure out?” (Teacher Edition, page 239).
- Lesson 13: “Display slide A. Give students 30 seconds to consider the questions on the slide on their own and then discuss it as a class. Say, last class, some of you mentioned having to get out of water when there was lightning. We have also noticed that lightning tends to be more common when it is humid. Let’s think about lightning and water” (Teacher Edition, page 257).

Student learning is frequently driven by students’ questions, ideas, and prior experiences. Related evidence includes:

- Lesson 1: “Draw on excitement about the phenomenon to motivate sharing of stories. Use student language about lightning to emphasize the ways in which it evokes memories and experiences. Say, whether we have seen lightning in our area a lot or not, we probably have some interesting thoughts about what lightning is or what it means” (Teacher Edition, page 35).
- Lesson 1: “Collaboratively develop the Driving Question Board. Display slide CC and gather students in a Scientists Circle. Say, As we build our DQB, it is important that we hear everybody’s questions, and we might find that we have questions similar to some of our classmates’ questions. We want to group and organize our questions so that they can help us guide our investigations and keep track of what we want to figure out” (Teacher Edition, page 53).
- Lesson 2: The materials provide three paths for the teacher to use, based upon student responses in a discussion, to support students in figuring out the role falling water plays in the phenomenon of lightning strikes (Teacher Edition, page 63). Each path helps students see themselves as drivers of the learning.
- Lesson 3: Teachers are instructed that the “next two questions do not appear on a slide and are meant to feel emergent from the class discussion rather than teacher led” (Teacher Edition, page 89). This strategy of not placing the questions on the slide but having questions emerge from the student discussion helps support students feeling that it is their discussion ideas that are driving the next learning segment about static rather than following a pre-determined path.
- Lesson 4: Students develop questions that lead to the next lesson. “What questions do we have about the relationship between matter and forces (like charged matter and forces from electric fields)? Why is an object or particle charged? How can friction cause an object to get a charge?” (Teacher Edition, page 108).
- Lesson 5: “When students have completed the electronic exit ticket, distribute Our DQB Questions with the list of questions developed on the Driving Question Board. Have students work individually to mark questions they think the class has answered using the key on the handout and on slide EE” (Teacher Edition, page 132).
- Lesson 6: Students revisit DQB progress and continue exploring the phenomenon. The class identifies questions on the DQB that have been answered such as “what leads up to a lightning strike?” or “what happens in the sky to cause a lightning strike?” (Teacher Edition, page 139).
- Lesson 6: As students prepare to read the article about how lightning strikes, they respond to the prompt, “Why are we reading this article?” with sample responses like “To find out more about lightning” and “To figure out what lightning has to do with static” (Teacher Edition, page

141). Having students explain the need to know that leads toward the need to read provides student motivation and a sense of student-directed learning from the student point of view.

- Lesson 7: "Elicit student ideas about the investigation. Suggest that we could use electrostatic forces, instead of our hands, to cause pushes or pulls on the scale. Ask, How could we use other classroom materials to measure electrostatic forces with the scale?" (Teacher Edition, page 156).
- Lesson 8: Student ideas about attraction between objects after working with the simulation are used to spur further conversation as teachers are asked to "Have students individually model what they think happened to the atoms in the paper when the balloon was brought close to them. Prompt them to consider that the paper clip did not become charged the way the balloon did, but that the paper was attracted to the balloon—how can we model that with the paper clips? How can we show that the paper stood on end, but then fell back down as soon as we took the balloon away?" (Teacher Edition, page 181).
- Lesson 9: "Revisit the Driving Question Board. As students wrap up their reflections, display slide G and direct them back to Our DQB Questions that they have in their notebooks from Lesson 5. Have students take a few minutes to continue analyzing the DQB questions" that have and have not yet been answered (Teacher Edition, page 194).
- Lessons 10–11: At the beginning of the lesson, students connect to the prior lesson by looking back at the M-E-F poster they developed and used in that lesson. They determine that many of their remaining questions are about energy and decide to focus on energy as their next step in their journey to figure out the lightning phenomenon (Teacher Edition, page 204). As they explore energy transfers, their questions like "Where did that energy come from?" (Teacher Edition, page 205) create a need to know that leads to the next activity. At the end of the lesson, students realize that they are still unsure about why lightning "strikes all at once instead of charges moving toward each other constantly?" (Teacher Edition, page 215). At the beginning of Lesson 11, students talk with a neighbor about questions left from the end of Lesson 10 about why the negative charges build up and "then make this massive 'jump' to the ground all at once…" (Teacher Edition, page 222).
- Lesson 12: Students are asked to reexamine the DQB and "…look over the list of questions and chat with a partner about what they are still wondering about. Ask, what from our Driving Question Board have we not answered yet?" (Teacher Edition, page 239).

Suggestions for Improvement

None

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 because each of the three dimensions is present throughout the unit and student expertise with most grade-appropriate elements for each band is either developed or used throughout the unit to support sense-making around the central phenomenon. However, there is a significant mismatch between the claims and evidence of student use and development of CCC elements, along with other mismatches for Science and Engineering Practices (SEPs) and Disciplinary Core Ideas (DCIs).

Science and Engineering Practices (SEPs) | **Rating: Extensive**
The reviewers found extensive evidence that students have the opportunity to use or develop the SEPs in this unit because students regularly use a majority (although not all) of the claimed SEPs to support students in sense-making about the central phenomenon. Students have opportunities to develop most of the claimed focus SEPs and to use many of the SEP elements that are not identified as being developed in this unit.

The following SEP elements are claimed as being intentionally developed in the unit.
Developing and Using Models

- *Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.* (SEP **2.1**)
    - Lesson 5: During the roundtable discussion, students are asked to consider their paper clip models, pencil and paper models, and computer simulations. A Supporting Students callout instructs teachers that “The paper clip models will continue to be a tool for students throughout the unit, in conjunction with pencil and paper models and computer simulations, as they develop increasingly complex mechanisms that bridge between subatomic structures and macroscopic phenomena. Elicit limitations, such as the fact that these ‘atoms’ are two-dimensional, while real ones are three-dimensional,

and reflect on how we could easily pull up the simulation or develop a three-dimensional model to provide this alternate perspective" (Teacher Edition, page 126). However, suggested student-facing prompts and sample student responses do not show evidence of students recognizing limitations of the models.

- Lesson 12: Students identify the merits and limitations of two models that show how lightning rods function to protect buildings and use evidence from different sources to support their evaluation (Teacher Edition, pages 246–248). A Supporting Students callout asks teachers to explain that supporting our "thinking in how gathering new information from multiple sources provides us with a way to evaluate limitations of models. Stress that the models we made in Lesson 11 were not wrong; we were working with the information we had at the time. Tell students that this is a common occurrence in science; models evolve as scientists learn more about the phenomena they study" (Teacher Edition, page 248).
- Lesson 13: Students evaluate three models. "Each time you examine a model, work with your partner to: ● Start by examining your checklist to look for the key ideas we need (Table 2). ● Rate the explanatory power of each model for the two questions [scale of 1–10] (Table 3). ● Use Table 4 to decide whether you accept it as valid. a. If so, what key ideas should you add to the list? b. If not, explain why not in the second table on your handout" (Lesson 13 Slides, Slide V).

- *Design a test of a model to ascertain its reliability.* (SEP **2.2**)
  - Lesson 4: Students are instructed to plan for an investigation to test differing interactions between objects. Teachers are encouraged to "…give feedback or push them to think deeper or be more specific in their plans and how they will serve as a test of model reliability" (Teacher Edition, page 100). Teachers are provided with a prompt to have students "consider the patterns that would provide evidence of reliability and the materials that could help them do that" (Teacher Edition, page 100). However, after students conduct their investigations, the ensuing discussion does not include any prompts for students to discuss the evidence of model reliability they saw in their results and to refer back to their ideas from the beginning of the lesson about testing for model reliability. Without this follow-up discussion, it is likely that students will not have engaged in this practice element enough to develop and later use it in another application.
  - Lesson 4: In a Supporting Students callout, the materials ask teachers to "Emphasize to students that our models are only useful if they are able to consistently explain phenomena across a variety of similar situations" (Teacher Edition, page 97), thus developing student understanding of this practice element and why it is important for models to provide consistency in order to be reliable.
- *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.* (SEP **2.3**)
  - Lesson 1: Students review aspects of modeling such as components, relationships, interactions, and mechanisms (Slide O) before beginning their initial model to explain what they have figured out about lightning so far (Teacher Edition, page 43).

- Lesson 1: “Individually develop initial models. Direct students to work on their own to use the components they listed to develop their initial model. Guide them to use words and/or drawings and point out the ‘zoom in’ space. Remind students that we thought a lot about how to explain phenomena at the particle level in the last unit, so we want to continue using that scale of thinking about the different parts of a system to make sense of this phenomenon, too. Also remind students to complete the explanation part of the handout. They should refer to the ‘Patterns We Notice About Lightning’ poster from day 1 and choose one of those ideas to explain how that factor impacts differences in lightning” (Teacher Edition, page 45).
- Lesson 1: “Suggest that students spend two minutes individually revising their models to include matter, and another two minutes revising them to include energy. Ensure that students are not just adding these components, but drawing relationships to other parts of the system” (Teacher Edition, page 46). Student revisions are specifically supported to illustrate relationships between energy and matter and the other components of the system. Students are also supported in the “zooming in” on a bolt of lightning as part of the modeling process (Teacher Edition, page 47).
- Lesson 4: Students integrate data collected following the use of the water dropper system to “Revise lesson 3 models to account for attraction and repulsion in the system…based on peer and teacher feedback and empirical evidence from the investigations” (Teacher Edition, page 103).
- Lesson 9: Part 2 of the Gotta-Have-It Checklist asks students to “Use your checklist to develop a model to answer the question” and a sample model is included in the key (Teacher Edition, pages 370–372).
- Lesson 9, Assessment: Question 1a asks students to “Draw a model using the subatomic structure of an atom to explain what is responsible for that change in charge” (Teacher Edition, page 352) and Question 1b asks students to “draw a model of one particle of Object C to help answer” the question (Teacher Edition, Static Interactions Rubric, page 353).
- Lesson 10: Students use a computational model to observe and illustrate the relationships between charged particles, energy, and forces. They revise their class M-E-F poster to show the relationship between energy, forces, and matter based on the evidence they observed in the computational model (Teacher Edition, pages 205–211). Students use their class model to predict what is happening with energy flows and use the computational model to check their predictions (Teacher Edition, page 208). A Supporting Students callout explains that “Students should use both the computational model and the M-E-F poster to revise their models from Lesson 9 and explain how lightning is able to transfer so much energy from the cloud to the ground” (Teacher Edition, page 213).
- Lesson 14: Students develop models using a checklist that includes components, relationships or interactions, and mechanisms. “Build a model to explain: Why is it safer to be away from water and in a building with lightning protection during a storm?” (Lesson 14 Slides, Slide E). After peer review, students revise their models. “Have

students return to the partner they brainstormed the Gotta-Have-It Checklist with, review their feedback, and then update their models based on that feedback. If time allows, ask students to share some examples of how the peer feedback helped them in their modeling" (Teacher Edition, page 288).

- *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.* (SEP **2.4**)
    - Lesson 2: Students review their initial models and answer the question, "What merits (strengths) and limitations (weaknesses) does our model have that affect what it can explain?" (Lesson 2 Slides, Slide K). Later in the lesson, students determine merits and limitations of a physical model.
    - Lesson 5: Students develop and/or use multiple types of models in order to figure out and explain the substructure of atoms and their charges and how these can begin to explain what is occurring at the subatomic level during a lightning strike. Students observe a sticky tape phenomenon, and their questions lead them to read about atomic structure and view the models it presents (Teacher Edition, pages 116–120). Further questions lead them to use a computerized atom simulation to synthesize information from the reading and simulation to explain atomic structure (Teacher Edition, pages 121–123). They develop models of an atom, including one that they draw and identify limits of, and a physical model, in which they can move the electrons (Teacher Edition, pages 123–127). They recognize the visual limitations of this model in representing a nucleus. Throughout the lesson students move between different models at different scales to explain the micro and macro interactions and phenomena.
    - Lesson 8: Students use a simulation of static attraction and respond to these questions as a class. "We have used different models in this unit. ● What merits (strengths) does the simulation have that the other models do not? ● What are some limitations of this simulation? ● How would zooming in with a paper clip model help us better understand what is actually happening?" (Lesson 8 Slides, Slide G). Students use their understanding of the different models to explain lightning polarization. "Use words and images to explain, What is happening at the atomic and subatomic level in a lightning strike? Make sure that you explain what is happening at the atomic and subatomic level in terms of electrons, charge, partial charge, and polarization. Explain how you used the simulation and the paper clip model to arrive at this explanation" (Lesson 8 Handout, Explaining Lightning Polarization).
    - Lesson 10: Students revise their models, using information from their own models, the class generates an M-E-F model and the checklist of important components. They develop a class model to illustrate the energy transfers they observed in the computational model, and then add these ideas about the relationships between charged particles, movements, and energy transfers to their M-E-F model (Teacher Edition, pages 207–211). They determine that a limitation of these models is that they do not explain the lightning phenomenon, so they apply the ideas they learned about the relationships between energy, forces, and matter to their models of lightning (Teacher Edition, pages 211–215).

- *Develop and/or use a model ~~(including mathematical and computations)~~ to generate data to support explanations, predict phenomena, analyze systems, ~~and/or solve problems~~.* (SEP **2.6**)
    - Lesson 3: Students test objects in the water dropper system (physical model) with a goal of trying to answer questions on the DQB. Students answer questions about their testing. "What types of interactions did you notice? What evidence of energy transfer to or from your test object did you observe, if any?" (Lesson 3 Slides, Slide E). Students are encouraged to "…use 'detectors' such as light bulbs, balloons, or other objects that may attract to or repel from the water dropper system to deepen their understanding of how this system works as a lightning analogue (macro vs. micro scale)" (Teacher Edition, page 80).

Obtaining, Evaluating and Communicating Information

- *Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, ~~concepts, processes~~, or information presented in a text by paraphrasing them in simpler but still accurate terms.* (SEP **8.1**)
    - Lesson 6: Students read an article, determine central ideas, and summarize the information…by paraphrasing it in simpler but still accurate terms. The article, *How Lightning Strikes*, states that "This reading was adapted from a paper written by scientists about their research, so it is structured differently from some types of text that might be more familiar to you" and references to sources are listed at the end (How Lightning Strikes, pages 1 and 4). Although the reading selection is well written for student comprehension at the high school level, is adapted from a paper written by scientists about their research, and provides students with scientific information that they can directly apply to what they are figuring out about lightning, evidence in the article indicates that the degree of adaptation from primary scientific literature has removed some essential elements of primary scientific literature that are expected to be encountered by students at the high school level, such as research methods and data, so the *scientific literature* part of the claimed key element is not supported by the reading selection.
- *Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question ~~or solve a problem~~.* (SEP **8.2**) (Strikethrough in course materials.)
    - Lesson 5: Students use their observations of the sticky tape investigation, a reading about atomic structure, and a simulation about the effect of adding electrons to the charge of an atom to understand the role of subatomic structures. "*How does the information from the simulation and reading help explain what is happening to the sticky tape?* Electrons must be moving off of atoms from one piece of tape to the other, making the charge change" (Teacher Edition, page 122).
    - Lesson 12: Students are asked to integrate data collected from four stations to answer the questions "what did the data say about where we should go during lightning? What did the data say about where we should not go? What did the data say about the types

of structures or materials that seem safe? What did the data say about the types of structures or materials that seem unsafe?" (Teacher Edition, page 241).
    - Lesson 12: Students read about lightning rods, with the option of using a new protocol called Connect, Extend, Question. They integrate this information with the data and safety tips they examined earlier in the lesson in order to explain why some materials are safer than others when there is lightning (Teacher Edition, Lightning Rods, pages 242–243). A Supporting Student callout states, "Students encounter multiple pieces of information which can serve as evidence in their explanation of conductivity: data, a reading, and models. They should use pieces of all of these in their final explanation" (Teacher Edition, page 248).
- *Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.* (SEP **8.3**)
    - Lesson 11: "Organize students into groups of 3 or 4. Display slide K and distribute Gathering Information. Talk through the directions on the slide so that each group has a successful research experience. Explain that the goal is for each group to bring information to the class from 1 or 2 reliable sources. Give students the remaining class time to complete Parts A, B, and C on the handout" (Teacher Edition, page 225). Students are asked to consider and respond to prompts asking "who wrote this? Is the author an expert in the area they are writing about?" as well as "who do they work for? Is that group known for independent, trustworthy information based on evidence, or might it have a bias? Is it trying to sell a product or persuade you about an idea?" (Lesson 11 Handout, Gathering Information, page 1).
- *~~Evaluate the validity and reliability of and/or~~ synthesize multiple claims, methods, and/or designs that appear in scientific and technical text or media reports, verifying the data when possible.* (SEP **8.4**) (Strikethrough in instructional materials.)
    - Lesson 13: Students are asked to evaluate multiple claims from several sources and "evaluate the claim's accuracy by checking a box to describe it as fully accurate, partially accurate, or not accurate. Use evidence and ideas we figured out during this lesson and unit to verify the accuracy of the claims and explain how this evidence supports your evaluation of the claim" (Lesson 13 Handout, Lightning Safety Claims, page 1).
- *Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, ~~mathematically~~).* (SEP **8.5**) (Strikethrough in instructional materials.)
    - Lesson 11: After their research, students communicate their information orally with the class during a building understandings discussion in which paper clip models are used to help communicate what they read about. After the reading of *Power of Lightning*, students communicate through both words and proposed energy transfer models to make the processes they read about clear to each other (Teacher Edition, pages 230–232).
    - Lesson 14: On the end-of-unit assessment, students communicate responses to questions in written form as well as drawing models.

The following SEP elements are described in the materials as "keys to sensemaking (sic)."

Asking Questions and Defining Problems

- *Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.* (SEP **1.1**)
    - Lesson 1: In an initial ideas discussion, students share aloud with the class what they noticed and wondered about the lightning phenomena they observed by carefully, and sometimes repeatedly, watching several videos in real time and in slow motion (Teacher Edition, page 35). Students therefore ask questions that arise from careful observation in order to seek additional information.
    - Lesson 1: After students examine a map of lightning fatalities and compare the data to a prior prediction, students ask questions to further understand the incidence of fatalities caused by lightning (Teacher Edition, page 41).

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 13: Students first plan an investigation. "Use mathematical thinking to plan your investigation. Use the table below to: Determine the different percentages, greater than 0.00% of salt in the water you want to test. Then calculate the mass of salt needed to make those percentages. Outline a procedure for how you will plan to use the limited amount of supplies available to test the percentages of salt you identified in order to collect data" (Lesson 13 Handout, Salt Investigation Plan). As they carry out the investigation and look at the data, they relate their findings to the phenomenon of the geese killed in the river. "As students are planning and carrying out their investigations, ask them how they are generating evidence to address their claims that lightning killed the geese in the St. Lawrence River. After the investigation, as students are answering question 6 on Salt Investigation Plan, make sure that students are using evidence from their investigation in their response" (Teacher Edition, page 262).

Using Mathematics and Computational Thinking

- *Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.* (SEP **5.2**)
    - Lesson 7: First, the class discusses how the variables observed in their investigation affect the strength of the forces. "How do the following variables appear to affect the strength of the forces between objects in the system? ● Top object's charge (qA) ● Bottom object's charge (qB) ● Distance separating the charged objects (r)" (Lesson 7 Slides, Slide M). Then the class considers the equation representing "one proposed model scientists have developed for some of the relationships we identified" (Teacher

Edition, page 161). Students are then asked to use calculations requiring Coulomb's Law to make predictions about the charge of objects in the class system as well as the distance between charged objects under different conditions (Comparing Force Relationships, page 1).
    - Lesson 9, Assessment: Questions 2a, 2b, 2c, and 2d require students to use algorithmic representations of phenomena to describe the relationships between the components of a system of static interaction or to predict the actual value of the force of attraction in the balloon/can scenario (Teacher Edition, Static Interactions Rubric, pages 355–359).
- *Apply techniques of algebra and functions to represent and solve scientific and engineering problems.* (SEP **5.3**)
    - Lesson 7: "Distribute Solving for Force. Pair students with a partner and say that they will determine forces using these larger-scale distances and charges. Explain that each partner will use Coulomb's law to solve for the force between ground and cloud" (Teacher Edition, page 168). Students are asked "How do our calculations from lightning compare to the forces we measured [using the water dropper]? Why is that? What do you think the difference in those forces means? How can you use what we figured out today to help explain what causes so much charge to move so quickly during a lightning strike?" (Teacher Edition, page 170).

Constructing Explanations and Designing Solutions

- *Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.* (SEP **6.1**)
    - Lesson 7: The class discusses the relationship between the different variables. "How does the amount of charge on the top object (q_A) appear to affect the strength of the forces in the system? More charge on the top object produces stronger forces in the system. How does the amount of charge on the bottom object (q_B) appear to affect the strength of the forces in the system? More charge on the bottom object also produces stronger forces in the system. How does the distance between the charged objects (r) appear to affect the strength of the forces in the system? Greater distances produce weaker forces in the system. Smaller distances produce stronger forces in the system". Although the materials state that "students make qualitative predictions (before investigation) and claims (after investigation) regarding the relationships among distance, charge, and force" (Elements of NGSS Dimensions, page 3), note that the materials provided do not indicate that students identify or explicitly use the idea of independent or dependent variables in their work.

Engaging in Argument from Evidence

- *Evaluate the claims, evidence, and or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* (SEP **7.2**)
    - Lesson 13: Students evaluate claims related to lightning safety and water by using evidence from their investigation and models. Students use the ideas they shared about

what they think caused the instantaneous death of geese in a scenario presented on Day 1 (Teacher Edition, page 257), and their investigation data to assess claims about lightning safety by evaluating the claims, evidence, and the reasoning behind the claims and determine the merits of their arguments (Teacher Edition, pages 275–276).

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 the DCI elements claimed are used to support student sense-making of the central phenomenon and students are engaged in grade-appropriate DCI elements throughout the unit as they attempt to make sense of the mechanism, context, and implications of lightning strikes.

DCI Category addressed (or not addressed)

PS1.A: Structure and Properties of Matter (Focal Area)

- *Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons*. (**PS1.A.1**)
    - Lesson 5: Students read and answer questions about atomic structure. "What are the smaller parts of the atom the scientists discovered? ● What properties did the reading tell us about these smaller parts?" (Lesson 5 Slides, Slide J). Then the class creates a poster with information about each subatomic particle, the charge, the relative mass, and the location (Teacher Edition, page 120).
    - Lesson 9: Students are given an assessment in which they are asked to "draw a model using the subatomic structure of an atom to explain what is responsible for that change in charge" and to be sure to include "the general location, name, and charge of all subatomic particles in any atom" (Static Interactions Assessment, page 1). Note that although ideas about electrons and charged matter are included in the Gotta-Have-It Checklist Key, evidence from the list on the Gotta-Have-It Checklist Key does not indicate the idea that an atom consists of a *nucleus, which is made of protons and neutrons, surrounded by electrons* (Teacher Edition, Gotta-Have-It Checklist Key, pages 369–370). The model of what is happening in a cloud that causes a lightning strike does include some zoom-ins that show an atom with its subatomic particles, but the labels for the nucleus, protons, neutrons, and electrons are not included.
- *The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.* (**PS1.A.3**)
    - Lesson 8: Students are asked to "think back to the balloon, paper scraps, and their paperclip models to help them reason through what is happening to the ground. Give students time to write their explanations. Encourage students to give detailed, particle-level explanations; they should not say that atoms become charged or polarized—they need to say what is happening to the electrons of those atoms when they become charged or polarized" (Teacher Edition, page 184).
    - Lesson 11: Students discuss the composition of air and determine that it doesn't conduct electrons very easily because the molecules are far apart and compare this to the closer molecules in ground which more easily conduct electrons. Students conduct

research about charges moving through the air and share their findings about the structure of the matter in air and the electrical forces within and between atoms, including the formation of ions (Teacher Edition, pages 225–227). Students are asked to identify the explanation that "best illuminates the cause-and-effect relationship between lightning and molecules in the air to form nitrates," and the best answer describes that "the energy from lightning transfers into the fields around charges in the air. This causes attraction between ions and other particles in the air to form new molecules (nitrates)" (Lesson 11 Exit Ticket Key, page 4).

- Lesson 13: Students use what they have learned about the structure and interactions of matter at the bulk scale and apply this to the electrical forces within and between atoms as they explain their saltwater investigation (Teacher Edition, pages 264–268).

PS2.B: Types of Interactions (Focal Area)

- *~~Newton's law of universal gravitation and~~ Coulomb's law provide mathematical models to describe and predict the effects of ~~gravitational and~~ electrostatic forces between distant objects.* (**PS2.B.1**). (Strikethrough in instructional materials.)
  - Lesson 7: The class discusses using Coulomb's Law to predict the strength of a force in the large-scale system of lightning. "Make predictions using the equation. Display slide T. Say, We want to think about what this means at larger scales, like lightning. Let's think about what the equation predicts would happen when we change some of these variables by one order of magnitude or a factor of ten. How would 10 times the number of charges in q_A affect the force? It should be ten times as strong. How would 10 times the distance of separation r between the charged objects affect the force? It should be 1/100th as strong" (Teacher Edition, pages 164–165). Students generate and use a Google Sheets computational model to explore the relationship between differences in charge and distance on the resultant attractive force and students are asked "how closely did the predicted graphs of force vs. distance from the equation fit the graphs from the investigation data?" (Teacher Edition, page 167).
  - Lesson 9: On an assessment, students use Coulomb's Law to explain the interaction between a charged balloon and a can. The examples of student responses show their thinking. "What to look for in students' mathematical thinking: 2a. The balloon that was rubbed for 30 seconds (trial 3) has the greatest charge, so it will have the greatest force of attraction between it and the can OR Coulomb's law describes that the greater the charge magnitude, the greater the attraction" (Lesson 9 Rubric Static Interaction Rubric, page 6).
  - Lesson 9: "Based on this data and what you know about Coulomb's Law, which mask would you predict to be the most effective in a controlled test?" (Lesson 9 Assessment N95 Mid-unit Assessment, page 4).

- *Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space.* ~~*Magnets or electric currents cause magnetic fields, electric charges or changing magnetic fields cause electric fields.*~~ (**PS2.B.2**)
  - Lesson 2: Students discuss matter and energy flows in the water dropper system. "What matter is moving? Water. How is energy transferring? It has to be moving through the system as the water moves. It goes between the pennies" (Teacher Edition, page 69). The materials identify that the forces at a distance portion of this element is fully addressed in this lesson. This activity addresses the portion of the element claimed, *Forces at a distance permeate space.*
  - Lesson 3: The materials identify that the *forces at a distance…permeating space* portions of this element are addressed in this lesson. A sample student response to the prompt "How might these objects help us figure out more about the water dropper system?" includes "It could help us see if there was some sort of attractive force in the system pulling on stuff in the space around it (kind of like a magnet)" (Teacher Edition, page 79). However, it is not clear what might cause students to volunteer this response before doing the investigations. During the investigations, students observe attractions and repulsions such as objects moving closer or farther from the water in the dropper without touching it. A margin callout instructs the teachers to "Make sure the class agrees that the terms for the interactions they see are attraction and repulsion" (Teacher Edition, page 81). A teacher note states that "This lesson is laying the groundwork for the idea of forces as the mechanism for energy transfer by introducing evidence of both forces and energy transfer in the water dropper system without naming them (yet) explicitly" (Teacher Edition, page 85). During the discussion, the teacher is instructed to "Highlight the evidence we have for push/pulls (forces) acting on the test objects in the system" (Teacher Edition, page 86). A "key takeaway around the idea that the objects in the system can also interact with forces, not just other forms of matter or energy" (Teacher Edition, page 88) is discussed and the class adds "force(s)" to the matter-energy diagram they created during OpenSciEd Unit C.
  - Lesson 4: "Conduct investigations. Display slide D. Say, our goal with this investigation is to better understand the system itself and to try and answer some of the questions on our DQB. Now is your chance to see how the objects you brought in interact with the water dropper system! Give students seven minutes to conduct investigation with the objects of their choosing and to record their noticings and wonderings for each object they test" (Teacher Edition, page 80).
  - Lesson 9: Students respond to a question on the assessment. "1b. Why was Object C attracted to your charged Object A? Draw a model of one particle of Object C to help answer this question. Be sure to include: how Object A's charge is involved what's happening with electrons in Object C the cause of the attractive force the role of fields in this process." Elements of expected student responses are provided. "+ Charges generate fields, which result in forces between charges. + Opposite charges cause an attractive force; like charges cause a repulsive force. + When I brought Object A close to Object C, the net charge of Object A caused the electrons in Object C's atoms to move: if

Object A had a positive charge, it attracted the electrons in Object C's atoms. if Object A had a negative charge, it repelled the electrons in Object C's atoms" (Lesson 9 Rubric Static Interactions Assessment, page 3).
    - Lesson 10: Students generate models to "establish that energy stored in the field transfers to the particles when oppositely charged particles come together and that energy transfers from particles to the field when those same particles move apart" as they are asked "what caused there to be more energy stored in the field in the system? Where did the increased energy in the field come from? How did the energy transfer when the charged particles were moved apart, and transferred to the particles as they move toward each other" (Teacher Edition, pages 206–207).
- *Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter,* ~~*as well as the contact forces between material objects.*~~ (**PS2.B.3**). (Strikethroughs in instructional materials.)
    - Lesson 1: This lesson is identified as supporting the "*atomic scale explain the structure, properties, and transformations of matter"* portion of this element. The discussion on energy and matter includes student sample answers such as "Other matter is involved, like water or air" and "If we know lightning is matter or energy, that might mean it is caused by changes in matter or energy" (Teacher Edition, page 46). The discussion and models include ideas about matter particles, such as in the air, ground, clouds, or rain and includes a bit about matter changing (Teacher Edition, pages 49–51). However, these are initial discussions that include large areas of uncertainty, so this lesson serves to introduce students to the concepts in this DCI element as a basis for it being further developed in later lessons.
    - Lesson 6: Students read about "How Lightning Starts" and are asked to consider "what information did you get from the article to answer our question? What static interactions are happening in the sky, according to the reading? Where are the electrons coming from that are causing these static interactions?" (Teacher Edition, page 142). Evidence in the reading text, discussion prompts, and sample student responses does not indicate that students identify the processes they are reading about or viewing in the cloud diagram as a transformation of matter.
    - Lesson 12: After considering molecular models of different materials, students discuss how the molecular structure determines if the material is a conductor of electricity. "What materials have we been discussing so far? Metals. Trees, so wood. What do you think is different about them at the atomic scale that could explain why some are safer than others? Something about their electrons. Maybe some things have more electrons or the electrons are in a different place or do different things?" (Teacher Edition, page 244).
    - Lesson 13: "Introduce ionic compounds. Say, so salt does not conduct when it's solid, and we think that is because the positive and negative neutralize each other. But when it dissolves it splits up? Display slide T. Tell students that since salt is a substance made of these ions, it is called an ionic compound, and that the sodium and chlorine are held together by what is called an ionic bond. Remind students that in Lesson 12 they saw

some examples of bonds in the models and that this is another example" (Teacher Edition, page 266).

PS3.A: Types of Interactions (Focal Area)

- *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~~.* (**PS3.A.1**). (Strikethroughs in instructional materials.)
  - Lesson 10: Students explore the idea of energy conservation using a computational model that shows energy transfers into and out of fields in a system when charged objects are pulled apart with the same or different charges (Teacher Edition, pages 205–209). Students add a forces-energy line to their M-E-F poster (Teacher Edition, pages 209–211) and then revise their own models to show energy transferred in and out of a field and discuss conservation of this energy (Teacher Edition, pages 212–215). A Supporting Students callout states, "The energy transfer models students develop show that energy is conserved, even when it appears to come out of nowhere. Highlight that in situations where energy seems to have been created or destroyed because of a change in temperature or particle motion, it may have simply been transferred into or out of a field" (Teacher Edition, page 206).
  - Lesson 11: Students are asked to read a resource, Power of Lightning and "…they should record any new ideas in their notebooks that will help us think about connections between matter, energy, and forces" (Teacher Edition, page 230). Later, students are asked to use that information to consider "how could we show energy transfer as light (radiation) with our energy transfer models? How could we show energy transfer as sound (thunder) with our energy transfer models?" (Teacher Edition, page 231).
  - Lesson 12: Students use the readings and models to explain how the atomic level structure of lightning rods makes them function the way they do to protect buildings (Teacher Edition, pages 244–247). Although **PS3.A.1** is claimed for this section of the lesson, this discussion appears to support DCI element **PS2.B.3** more than **PS3.A.1**, since the discussion does not include conservation of energy.
- *At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.* (**PS3.A.2**)
  - Lesson 1: After students engage in a discussion about whether lightning is matter or energy, they revise their models to include initial ideas about how energy and matter play a role in lightning strikes. As they establish areas of agreement for their consensus model, they establish that there is evidence of energy in the warm temperature, sound of thunder, and/or flash of light (Teacher Edition, page 49). However, the sample model does not include the idea of sound (e.g., thunder), which is discussed in the lesson and specifically listed in this element. The model includes the idea of motion, which was listed as a possible area of uncertainty about what is moving between the clouds and the ground.

- Lesson 11: Students are asked to read a resource, Power of Lightning and "…they should record any new ideas in their notebooks that will help us think about connections between matter, energy, and forces" (Teacher Edition, page 230) and later, asked to use that information to consider "how could we show energy transfer as light (radiation) with our energy transfer models? How could we show energy transfer as sound (thunder) with our energy transfer models?" (Teacher Edition, page 231). Later, students are asked to consider multiple energy transfer models involving light, thunder, and nitrate formation when describing how energy transfers in different parts of the lightning phenomenon explored so far (Teacher Edition, page 232).

- *These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). ~~This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.~~* (**PS3.A.4**) (Strikethrough in instructional materials.)
  - Lesson 11: The class discusses how they can model the transfer of energy as light, sound, and to make nitrates. "How could we show energy transfer as light (radiation) with our energy transfer models? Have energy going from the field to particles. Show the particles speeding up, then energy transfers out as light. How could we show energy transfer as sound (thunder) with our energy transfer models? Have energy going from the field to particles. Say that the particles move apart, then come back together. Show the energy transferring to other particles through conduction/as sound. How could we show energy transfer to make nitrates with our energy transfer models? Have energy going from the field to particles. Show that electrons are removed, then energy is transferred to other particles as new molecules form" (Teacher Edition, pages 231–232).

PS3.C: Relationship between Energy and Forces (Focal Area)

- *When two objects interacting through a field change relative position, the energy stored in the field is changed.* (**PS3.C.1**)
  - Lesson 10: Using a computer simulation, students change the distance and direction of movement between two particles. Students answer questions based on their investigation. "a. What types of things can you do before you push the 'Play' button to increase the energy stored in the field in this system before the charges are released? b. How are the forces affected when you do those things that increase the energy stored in the field? c. How is the electric field affected when you do things that increase the energy stored in the field?" (Lesson 10 Handout Energy Charge Model, page 1). Later, students are asked to "look at your results for opposite charges and compare them to the result for like charges. What differences do you see? What general rules could we make about when there is a lot of energy stored in the field? Why is this important to consider when examining how lightning interacts with materials?" (Teachers Edition, page 209).

Crosscutting Concepts (CCCs) | Rating: Adequate

The reviewers found adequate evidence that students have the opportunity to use or develop the CCCs in this unit because most of the claimed CCCs are grade-band appropriate and are sufficiently represented throughout the unit to support student learning. For some of the claimed CCCs, students may not fully use the entirety of the claimed element, although no strikethroughs appear to be used to indicate whether or not this was intentional.

CCC Category addressed (or not addressed)

The following CCCs are claimed as being used to develop student proficiency during the unit.

Patterns

- *Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* (CCC **1.1**)
    - Lesson 1: Students are asked, "If we change the timescale—if we can slow the timescale down in the video—how would that help us notice patterns about the lightning?" (Teacher Edition, page 34). An accompanying margin callout states, "This brief discussion is intended to make explicit that different timescales allow for different observations and questions to arise from a phenomenon" (Teacher Edition, page 34). Students record and share what they noticed and wondered (Teacher Edition, page 35). However, in this lesson, students are not focused on providing evidence of causality and the discussion appears to specifically lead students to propose correlations prior to generating data to explore potential causality.
    - Lesson 1: Students analyze three graphs with lightning data on one slide. Depending on the size of the classroom screen, the timescale details in the three graphs displayed on Slide G may be difficult for some students to readily pick up on (Teacher Edition, page 38). This could make it difficult for them to analyze the graphs.
    - Lesson 8: Students engage with a simulation that highlights interactions between charged objects whose charges are not readily shown on the screen. Later that lesson, students "…individually model what they think happened to the atoms in the paper when the balloon was brought close to them. Prompt them to consider that the paper did not become charged the way the balloon did, but that the paper was attracted to the balloon—how can we model that with the paper clips? How can we show that the paper stood on end, but then fell back down as soon as we took the balloon away?" (Teacher Edition, page 181). In doing so, students contrast macroscopic representations with microscopic models in an attempt to gain insight into underlying causes of the observed pattern.
    - Lesson 9: Students are asked to use macroscopic observations and connect to microscopic behavior to better explain what is happening. "How did the charges on the atoms in Object A change when you rubbed Object A on Object B? Draw a model using the subatomic structure of an atom to explain what is responsible for that change in charge" (Static Interactions Assessment, page 1). Later, students consider patterns on the assessment when explaining why two charged objects are attracted to one another. "Support students in tying a mechanistic account to patterns. Ask, How did we see

charged and neutral objects interact in our investigations? What did the simulation show us about what this looks like at the particle level?" (Lesson 9 Rubric Static Interactions Assessment, page 3). Note that although many of the ideas listed in the Gotta-Have-It Checklist were figured out using patterns of evidence at different scales, the listed ideas do not describe patterns at different scales (Teacher Edition, pages 369–370).

  - Lesson 14: Students create their Gotta-Have-It Checklists as a guide for creating their models to address "why is it safer to be away from water and in a building with lightning protection during a storm" as they address questions such as "in this unit, we identified lots of evidence of patterns at different scales (global patterns form maps and data, visible evidence from investigations, particle-level evidence from simulations). Explain how this evidence supports your model at multiple scales" (Consensus Gotta-Have-It Checklist, page 3).

- *Mathematical representations are needed to identify some patterns.* (CCC **1.4**)
  - Lesson 7: Students graph results of an investigation to determine patterns in the data. "What would this look like on a graph? Sketch what you predict the graph of the relationship would look like for the force acting on the scale versus the distance between the like-charged objects" (Lesson 7 Handout Predicting Force Relationships, page 1). Later, students are encouraged to consider their individual and class-wide responses on the Comparing Force Relationships handout as the teacher asks them "how closely did the predicted graphs of force vs. distance from the equation fit the graphs from the investigation data?" (Teacher Edition, page 167). However, it is not clear that students understand that mathematical representations are needed to identify some patterns. The use of graphs as tools of mathematical representation seems to be a byproduct of the teacher's instructional decision-making rather than a core strategy that is being learned or practiced in this lesson.
- *Empirical evidence is needed to identify patterns.* (CCC **1.5**)
  - Lesson 4: The teacher is told to "Emphasize that we need direct or trusted indirect evidence from investigations or observations (empirical evidence) in order to be sure how charge applies to lightning and other phenomena" (Teacher Edition, page 96). A Supporting Students callout states, "Evidence is needed to identify patterns. In these investigations, evidence is in the form of the interactions students observe, as well as in the links between what they do to their materials—namely, rubbing the—and the interactions they observe: attraction and repulsion. The patterns of attraction and repulsion will be important to keep in mind later as students develop models of particle level charge transfer" (Teacher Edition, page 101). At the end of the discussion when students share the results of their investigations, students are asked to highlight any patterns in the types of materials that tended to attract or repel, and these patterns are included with the class data (Teacher Edition, page 102). A Supporting Students callout states, "Empirical evidence includes both experimental evidence and evidence from systematic observation. Patterns can be predicted from anecdotal evidence derived from everyday experiences, but empirical evidence can be used to confirm or provide

evidence against predicted patterns or identify previously unnoticed patterns" (Teacher Edition, page 102). Students conduct an investigation to determine interactions upon rubbing the objects they selected together. During the next day's discussion, students are asked "what new sources of information have we added in this lesson so far? What patterns do we understand better because of the tests we conducted?" (Teacher Edition, page 102). Students are therefore supported to begin building toward an understanding of this element.

- Lesson 13: Students generate and analyze data to show that an increase in the amount of salt in water caused an increase in conductivity. "How does adding salt to water affect the rate of charges moving through it? Adding salt increased the rate at which charges flowed through the water. The more salt we added, the more it conducted and the higher the number on the ammeter" (Teacher Edition, page 263). However, students are not required to use or engage with the idea that empirical evidence is required to identify patterns.

Scale, Proportion, and Quantity

- *The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.* (CCC **3.1**)
    - Lesson 7: "Point out that we have investigated a small-scale system, but we want to look at a larger-scale system like lightning. Ask, Since this equation can be used to predict the relationships among force, distance, and amounts of charge, how might we use it to make predictions for a larger-scale system? Listen for student responses such as: If we knew the distance from the ground to the cloud and also the electrostatic forces, we could figure out how many charges are in the system. If we knew the distance from the ground to the cloud and the amount of charge in the cloud, we could figure out how much electrostatic force the charges in the cloud are producing on other charges" (Teacher Edition, page 167).
    - Lesson 10: Students view statistics that show the immense amounts of energy transferred when lightning occurs. They see these amounts expressed in other scientific measurement units, such as joules and electron-volts, where they see the amount expressed in terms of what one of each measurement unit is equivalent to compared to the energy in a lightning strike. They determine that there "is a LOT of energy" (Teacher Edition, page 204) involved. As they progress through the lesson activities and apply what they learn to the lightning phenomenon, they continue to refine their ideas about the immensity of the scale and quantities of energy that occur with the interactions of huge numbers of charged particles transferring this energy into electric fields, and that this huge amount of stored energy transfers out of the field when lightning strikes (Teacher Edition, pages 209, 212–215). Student models include both atomic-scale charges and movement of those large amounts of charges in the macroscopic phenomenon of a lightning system (Teacher Edition, page 213). However, although several of the activities in which students apply what they have learned about energy transfer at an atomic level to the lightning phenomenon, and the idea of the immense

amounts of matter, energy, and force in a lightning system is developed, evidence shows only an indirect allusion to the idea that the *significance of a phenomenon is dependent on the scale…and quantity* of these components.

- *Some systems can only be studied indirectly as they are too small, too large, ~~too fast, or too slow~~ to observe directly.* (CCC **3.2**)
    - Lesson 3: Students employ the use of the water dropper system as they seek to generate data that will help them explain the interactions that occur in the larger scale lightning system (Teacher Edition, pages 80–87).
    - Lesson 5: Students revise their macroscopic explanations of what produces static charge with the information they gather about subatomic particles, which are too small to be seen, so they need to be studied indirectly. The information about the subatomic scale interactions guides their revisions as they explain what is happening on a macroscopic scale (Teacher Edition, pages 121–123, 128–130).
- *Patterns observable at one scale may not be observable or exist at other scales.* (CCC **3.3**)
    - Lesson 1: After examining graphs representing data at three different time scales and recording their observations and questions, students are asked to share with a partner their ideas related to the question "What patterns do you notice across the three graphs?" (Teacher Edition, page 38). If students do not pick up on the time scale differences, the teacher is given the prompt to ask students to focus on the x-axis or to look for how the timescales are different. Student observations are recorded on a piece of chart paper titled "Patterns We Notice About Lightning" (Teacher Edition, page 38). In a teacher callout, teachers are directed to "highlight to students that the general trend of the data is the same across the timescales, with week-to-week variation only visible on the rightmost chart. Point out that it is common when examining a phenomenon that some patterns only become visible when looking at a particularly large or particularly small scale of time or space" (Teacher Edition, page 38). This series of questions and instructions specifically draws out the ideas in this **Patterns** element.
    - Lesson 8: Students engage with a simulation that highlights interactions between charged objects whose charges are not readily shown on the screen. Later that lesson, students "…individually model what they think happened to the atoms in the paper when the balloon was brought close to them. Prompt them to consider that the paper did not become charged the way the balloon did, but that the paper was attracted to the balloon—how can we model that with the paper clips? How can we show that the paper stood on end, but then fell back down as soon as we took the balloon away?" (Teacher Edition, page 181). In doing so, students contrast macroscopic representations with microscopic models in an attempt to gain insight into underlying causes of the observed pattern. Both of these examples of the same pattern (attractive force between objects) are illustrated at two scales, but do not appear to be unobservable or nonexistent at either scale. As presented, evidence of its existence is present as is the ability to observe it (directly or via proxy measures), so it is unclear that students will develop this element during this lesson.

  - Lesson 14: As students create their Gotta-Have-It Checklists as a guide for creating their models to address "why is it safer to be away from water and in a building with lightning protection during a storm" they address questions such as "in this unit, we identified lots of evidence of patterns at different scales (global patterns from maps and data, visible evidence from investigations, particle-level evidence from simulations). Explain how this evidence supports your model at multiple scales" (Consensus Gotta-Have-It Checklist, page 3). Patterns are identified and used to highlight implicit or explicit causes of risks associated with being near water during stormy conditions. These patterns are not claimed to no longer exist at larger or smaller scales. The modeling activity appears to be intended to highlight the explanatory nature of changing scales for deepening a perspective that may not be available at another scale.
- *Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.* (CCC **3.4**)
  - Lesson 6: Students "use information from the reading to compare the lightning and classroom static systems. Display slide H. Say, this reading has helped us answer what is causing static interactions in the lightning system. We also have first-hand experiences of static interactions within our classroom. What is similar and different in terms of the static interactions between the lightning system we just learned about and the static phenomena we've explored in class?" (Teacher Edition, page 143). The concept of scale differences is specifically drawn out in the discussion. However, evidence does not indicate that students are using the concept of scale as a means to understand how a model at one scale relates to a model at another scale. In addition, evidence does not indicate that the numbers in the reading and the discussion are referred to as orders of magnitude during the reading or scale discussions.
- *Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).* (CCC **3.5**)
  - Lesson 7: The materials claim that "Students use algebraic thinking to evaluate how the trend in their data compares to the trend predicted by Coulomb's law, likely seeing a difference between linear and nonlinear decay" (Elements of NGSS Dimensions, page 7). In this lesson, students are expected to create a prediction about the graph of force vs. distance from their investigation data and the call-out box for "Supporting Students in Engaging in Using Mathematics and Computational Thinking" says that "students' sketches of the graph of the predicted relationship will probably be a linear one…later in the lesson, students will see that the graphs of the data they just made predictions about show a nonlinear relationship" (Teacher Edition, page 157). While this claim is borne out in the lesson, it does not appear that students use algebraic thinking to carefully examine data to make a prediction. Rather, it seems that their lack of familiarity with nonlinear functions/graphs is the more likely driving force behind their assumption of linearity.

The unit also uses the following CCC elements:

Cause and Effect

- *Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.* (CCC **2.1**)
  - Lesson 2: Students are asked to move about the room in response to their current belief about whether they agree with different statements on Slide G before pointing out that "…as students share their evidence, the only piece of that everyone is using is the graph. Have students consider if they have sufficient evidence to support their claims. Ask for a few volunteers to share their thinking, then send students back to their seats" (Teacher Edition, page 65). Students are then led through a discussion of the nature of correlation and causation before the teacher "take[s] students back to the initial consensus model. Display slide K and say, we have some disagreement about the type of relationship, causation or correlation, shown in the data. Models can be used to explain phenomena, so maybe if we tie this data back to our model it will help us out. Give students a minute to think about the two questions on the slide. Then, lead a discussion about how our initial consensus model could help us figure out if falling water really could be causing lightning. When students share their ideas about merits and limitations, record them on a piece of paper…" (Teacher Edition, pages 65–66). From here, students are prompted to consider the use of a physical model to further explore this phenomenon and collect data to better understand the factors at play. In the teacher support for formative assessment, the teacher is told "Accept all student ideas and push back only if all students are convinced that they can definitively state that falling water causes lightning or lightning causes rain. In this case, ask students to explain how that would work and remind them that we cannot be sure that one event causes another unless we have an explanation of the mechanism supported by experimental evidence" (Teacher Edition, page 65).
  - Lesson 4: This element is not claimed but is built toward. The teacher is told to "Emphasize that we need direct or trusted indirect evidence from investigations or observations (empirical evidence) in order to be sure how charge applies to lightning and other phenomena" (Teacher Edition, page 96).
  - Lesson 5: An Attending to Equity callout instructs teachers to remind students about the difference between correlation and causation by reiterating that seeing something similar does not mean they have the same cause (Teacher Edition, page 116). This note to teachers helps to ensure that students are using this **Cause and Effect** element, but only at the Grade 6–8 level because it does not include a discussion of the role of empirical evidence.
- *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.* (CCC **2.2**)
  - Lesson 11: On an Exit Ticket, students consider the best explanation of a cause and effect relationship between lightning and molecules in the air forming nitrates. They provide a rationale for their thinking. "Which explanation best illustrates the cause-and-

effect relationship between lightning and molecules in the air to form nitrates? The energy from lightning heats up molecules, causing them to react to form new molecules (nitrates). The energy from lightning transfers into the fields around charges in the air which. [sic] This causes attraction between ions and other particles in the air to form new molecules (nitrates). The energy from lightning causes particles to move apart and come back together. When they smash back together they react to form new molecules (nitrates). The energy from lightning causes particles to break up to form new molecules (nitrates). Correct response: The energy from lightning transfers into the fields around charges in the air. This causes attraction between ions and other particles in the air to form new molecules (nitrates). Rationale for distractors: Students should recognize that a temperature increase is not sufficient to form the new molecules, with the first part of the first explanation more closely resembling that for light emissions. Students should recognize that the third explanation more closely resembles that of thunder generation. Students should recognize that the fourth explanation, although related to middle school thinking about reactions, does not fully describe the situation they encountered" (Lesson 11 Answer Key Exit Ticket, page 4).
    - Lesson 13: Students are presented with several models that attempt to explain the interactions, at an atomic scale, that cause charges to move through salt water. They use the information they have gained in the lesson to determine which model best fits the evidence for the cause of charges moving through saltwater (Teacher Edition, pages 267–270).
- *Changes in systems may have various causes that may not have equal effects.* (CCC **2.4**)
    - Lesson 3: Students notice patterns in changing forces and energy when they conducted the water dropper system investigations and use these to explain the different effects they observe (Teacher Edition, pages 81–88). A Supporting Students callout explains that "This is an opportunity to help students realize that different objects or materials respond differently to the water dropper system. Although students will not figure out why that is during this lesson, this is a good moment to highlight the various directions and magnitudes of effects observed and to encourage students to wonder about underlying causes. Accept all student ideas. Students will fully answer these questions by the end of Lesson 5" (Teacher Edition, page 81).

Systems and System Models

- *Models (e.g., physical, mathematical, computer models) can be used to simulate system and interactions, including energy, matter, and information flows, within and between systems at different scales.* (CCC **4.3**)
    - Lesson 5: Students will "participate in a roundtable discussion. Display slide S. Say, let's share what we figured out about how the paper clip models can help us explain what we saw in the sticky tape investigation. Choose one group to demonstrate their models, and have them stand so all students in the Scientists Circle can see the demonstration. Ask the group to demonstrate their paper clip models for the four observations they modeled on slide Q. Record student ideas to the final prompt, not shown, on the slide,

on a sheet of chart paper. How did this group model the interactions similar to or different from how your group modeled them? How did moving electrons between the index cards impact their net charges? What does this help us visualize and understand about what is happening to the particles in the atoms that make up the sticky tape to cause static interactions?" (Teacher Edition, pages 126–127).

Energy and Matter

- *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.* (CCC **5.2**)
    - Lesson 9: The class completes a checklist of important ideas for their model revision that explains lightning. "When those collisions happen, electrons are brushed off of some of the crystals or molecules and move to other crystals or molecules (Lesson 6)." "Inside the cloud, negatively charged matter builds up at the bottom of the cloud, while positively charged matter collects toward the top of the cloud. The bottom of the cloud has many, many particles with extra electrons and a strong negative charge (Lesson 6)." "The more charges that accumulate on either side of the system, the stronger the attractive or repulsive forces get (Lesson 7)." "The accumulation of so many excess electrons/so much negative charge at the bottom of the cloud has enough force to cause the atoms in the ground to experience induced polarization and become partially positively charged (Lesson 8) even though the cloud is far from the ground (Lesson 7)." "Lightning is often between the bottom of the cloud and the ground because the bottom of the cloud is actually closer to the ground than the top of the cloud (Lesson 6)" (Lesson 9 Answer Key Gotta-Have-It Checklist).
    - Lesson 10: Students build a model to explain energy changes in the system and during the discussion, the teacher is encouraged to listen for the following ideas in particular "energy is stored in the space between the charges, where the electric field is, the electric field results from the forces between charges, energy is transferred into the field when particles are moved apart, and transferred to the particles as they move toward each other, [and] the total amount of energy remains the same whether it is stored in the field or as kinetic energy of particles" (Teacher Edition, page 206). Later, students revisit the M-E-F poster and while doing so, teachers are encouraged to use the forces-energy line to continue the discussion, ultimately listening for ideas that "energy transfers when there is a push or pull" and "energy transferred when objects or particles collide or exert a force on another," ultimately leading to a conclusion that "…forces can transfer energy" (Teacher Edition, pages 209–210).

Structure and Function

- *Investigating or designing new systems or structures requires a detailed examination of the properties of different components, and connections of components to reveal its function and/or solve a problem.* (CCC **6.1**)
    - Lesson 12: Models of the particles of metals and nonmetals are used to explain why metal are better conductors of electricity. "What materials have we been discussing so

far? Metals. Trees, so wood. What do you think is different about them at the atomic scale that could explain why some are safer than others? Something about their electrons. Maybe some things have more electrons or the electrons are in a different place or do different things?" (Teacher Edition, page 245).

- Lesson 14: "Question 1: A friend heard that airplanes can get struck by lightning and is wondering about how everyone on the airplane would be safe if this happened. Use the graphic and words to communicate how the design of the airplane works to protect the crew, passengers, and electronics. Annotate the graphic to show the location and flow of electrons in the metal covering of the airplane before and after the lightning strike. Use multiple formats (graphic, writing) to communicate the design and performance of the airplane's safety system to your friend. Explain how it protects the crew, passengers, and electronics inside during a lightning strike. Include scientific information about the relationship between the structures in the materials and how that leads to the functionality of the design (safety)." "The metal on the outside of the airplane contains free electrons just moving around. When lightning strikes the airplane, the electrons move to create paths for the lightning. This lets the lightning travel safely on the outside of the plane and not to the insulated materials inside. It is a lot like a lightning rod" (Lesson 14 Rubric End-of-Unit Assessment Rubric, pages 2–3).

Suggestions for Improvement

General

- Consider explaining the use of numbers to designate SEP, CCC, and DCI elements. For example, it could be helpful to explain the meaning of SEP **2.4**.

Science and Engineering Practices

Consider ensuring a close match between claims and evidence of student use and development of the claimed SEP elements. This could be done by clarifying the claims, or by providing additional supports in the lessons. For example:

- Modeling: In the Lesson 4 discussion in which students share investigation results, consider providing a student prompt that leads to a discussion about how their results did (or did not) provide evidence of the reliability of their model. The discussion could include a prompt to think back to their student responses at the beginning of the lesson. Similarly, in the Lesson 5 discussion, consider adding prompts that lead students towards discussing the limitations of the model.
- Since the article students read in Lesson 6, though a well written adaptation of writing by scientists, is lacking some aspects of scientific literature that are considered essential for the NGSS element that is claimed, such as research methods and/or data, consider changing the claimed element to one of the other **Obtaining, Evaluating, and Communicating Information** elements to better correspond with the type of article students read. Alternatively, consider adding a reference to the research methods used in the referenced sources.

- In the Lesson 7 discussion regarding the relationships of the variables, consider adding student prompts that lead to students explicitly identifying independent or dependent variables in their work.

Disciplinary Core Ideas

Consider ensuring a close match between claims and evidence of student use and development of the claimed DCI elements. This could be done by clarifying the claims, or by providing additional supports in the lessons. For example:

- Consider adding the idea of sound/thunder in the sample model in Lesson 1 since the idea is discussed in the lesson.
- Consider adding a prompt or activity in Lesson 3 that would lead students to use the idea that there were some kind of attractive forces in the system. Similarly, consider adding discussion prompts and adjusting products so that they clearly show that students are understanding and articulating that *forces are permeating space* in the investigations in Lesson 3.
- In order to engage students more fully in developing the connection between forces and matter in the Lesson 6 discussion after the reading and the cloud diagram about what is occurring in the cloud that produces lightning, consider connecting back to the diagram on page 140 to relate the concepts students read to their diagram showing matter and forces. Consider adding in language that helps students see what they read and saw in the cloud diagram as *matter being transformed* along with the forces involved.
- Consider either not claiming Coulomb's law in Question 1b of the Lesson 9 assessment or adjust the assessment so that Coulomb's law is utilized to answer the question.
- Consider adding the idea of electric fields to the Gotta-Have-It Checklist Key for Lesson 9.
- In Lesson 12, consider either including a discussion of the concept of conservation of energy to better match the **PS3.A.1** element, or changing the claimed DCI element.

Crosscutting Concepts

Consider ensuring a close match between claims and evidence of student use and development of the claimed CCC elements. This could be done by clarifying the claims, or by providing additional supports in the lessons. For example:

- In Lesson 1, consider including a suggestion to provide paper copies of the three graphs for some or all students so that they can more readily pick up on the timescale differences, especially if the classroom screen is not large enough for easy viewing of the timescale details.
- In Lesson 1, consider either not claiming CCC **1.1**, or adding a focus on providing evidence of causality in the discussion. Alternatively, the claim could be clarified, and a note could be included that explains how the student thinking in this lesson is foundational to thinking in terms of causality as they obtain more data, and that that is why this element is partially developed in the lesson.
- Consider adding a discussion about empirical evidence in Lesson 2 when students work with empirical evidence to analyze the graph of rain volume and lightning flash rates and when they observe the water dropper model. However, if the term empirical evidence was intentionally

not used in Lesson 2, consider adding a callout or teacher note at the points where empirical evidence is being used to explain why the term is not being used yet.

- In order to further deepen student understanding of what constitutes empirical evidence during the Navigate discussion in Lesson 4 (Teacher Edition, page 102), consider providing students with some of the information in the Supporting Students callout for teachers and providing an opportunity for students to look at evidence they have used in this lesson (and perhaps a prior lesson) in their figuring out process and identify the evidence that is empirical and that this type of evidence is required for determining patterns.
- In order to strengthen students' use of the CCC of **Scale, Proportion, and Quantity** in Lesson 6, consider adding language to the scale discussion that has students reflecting on how using the concept of scale helps them to understand how a model at one scale relates to a model at another scale. Also consider adding language that refers to the numbers in the reading as orders of magnitude.
- Consider further developing the use of graphs as tools of mathematical representation as a core strategy that students learn or practice in Lesson 7 rather than being a result of the teacher's instructional decision-making.
- In order to deepen the understanding of the CCC element *the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs,* in Lesson 10, consider adding a prompt that draws out the *dependent* aspect of this element, so that students articulate how the lightning phenomenon is dependent on the vastly huge amounts of energy, force, and matter that interact in a cloud system that produces lightning.

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that student performances integrate elements of the three dimensions in service of figuring out phenomena or designing solutions to problems. Students have several opportunities to tie together grade-appropriate SEP, DCI, and CCC elements in service of sense-making throughout the unit.

Students frequently use grade-appropriate elements of all three dimensions together in order to work toward figuring out a phenomenon or solving a problem. Related evidence includes:

- Lesson 2: Use and move between multiple types of models to determine where there is correlational or causal relationship between falling water and lightning. (SEP: **2.4**; DCI: **PS2.B.2**; CCC: **2.1**)
    - SEP: Students use different models at differing scales that address different components of a larger phenomenon as a means for gaining greater mechanistic and causal associations.
    - DCI: Students break down the phenomenon of lightning into components, including related events coincident with the phenomena. In this case, students come to learn more about the relationship between falling water and its association with lightning through an examination of causal and correlational links deduced through the examination of available evidence.
    - CCC: Students identify the limitations of data not empirically sourced to understand the need for more reliable data to provide a causal link between variables.
- Lesson 11: Communicate information in words and diagrams about the causes of energy transfer through light and sound. (SEP: **8.5**; DCI: **PS3.A.2**, **PS3.A.4**; CCC: **2.2**)
    - SEP: Students create an explanatory model intended to synthesize a reading and connect back to initial ideas developed within the unit about the nature of energy transfer and the underlying causes of energy transfer.
    - DCI: Students engage with the idea that energy can transfer through fields and through interactions with matter. To do this, students create an energy transfer model that highlights the specific changes in matter, energy, and forces using the connections they've formed relating to those ideas in the Power of Lightning reading as well as prior experiences in the unit.
    - CCC: Students use **Cause and Effect** to examine how the movement of energy results in differences at the atomic level.
- Lesson 13: Plan and conduct an investigation to generate empirical evidence in order to evaluate a claim about the conductivity of water (SEP **3.1**, **7.2**; DCI: **PS1.A.3**; CCC: **1.5**)
    - SEP: In this investigation, students use their knowledge of the concept of conductivity to put those ideas to the test as they collect empirical data about the impact of salinity on conductivity for various combinations of materials.
    - DCI: Students investigate the structure and function of bulk materials as a function of electrical charge by using the concept of conductivity as a stand-in for the molecular-level understanding being developed in this lesson.
    - CCC: Students generate and analyze data to provide empirical evidence that an increase in the amount of salt in water caused an increase in conductivity. However, students are not required to use or engage with the idea that empirical evidence is required to identify patterns.

Suggestions for Improvement

Applying the suggestions for improvement from Criterion I.B could provide students with more opportunities to use all three dimensions together in service of sense-making.

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that lessons fit together coherently to target a set of Performance Expectations (PEs) because each of the lesson-level PEs is clearly stated and reflects intended student learning outcomes as they build toward the targeted set of NGSS PEs. Each lesson also builds directly on prior lessons and the links between lessons are made clear to students using a variety of strategies, including providing students with opportunities to ask their own questions, using what students figure out as the next question to pursue, and answering questions generated by students in the previous lessons.

Lessons are connected coherently for students. For example:

- Lesson 1: Students begin Day 2 of the lesson with a brief discussion of what they figured out last class as well as revisiting what they were wondering about or what questions the data raised during Day 1 (Teacher Edition, page 43).
- Lesson 2: Students begin the lesson by recalling the activities in the last lesson in which they shared and organized questions, brainstormed ideas for investigations, and looked at areas of agreement. They share any new ideas for investigations or questions. They use their working model from Lesson 1 to figure out what step to take next (Teacher Edition, page 61).
- Lesson 2: At the end of the lesson, students are reminded of the Navigation Routine. "Say, Just like last unit, we will typically start and end lessons by taking stock of what we have done so far and what we want to figure out next. This helps us make sure that we do investigations that help us answer our questions" (Teacher Edition, page 71). This helps students be aware of the routine that connects their learning from lesson to lesson.
- Lesson 11: An Attending to Equity note explains that students do not need to know definitions for bonds or ionic bonding in this lesson, and that "Students will develop an initial definition of bonds in Lesson 12 and ionic bonds specifically in Lesson 12" (Teacher Edition, page 231).
- Lesson 12: Teachers are instructed to "Tell students they will go more in depth with this idea [types of bonds] in later units and for now you want to focus on electrons and conductivity" (Teacher Edition, page 245).

The lessons build coherently to develop a targeted set of PEs. Each lesson includes broken down versions of each targeted PE, but it is not clearly state which NGSS PE each lesson-level PE is intended to make progress toward. Related evidence includes:

- **HS-PS1-1**: *Use ~~the periodic table as~~ a model ~~to predict the relative properties of elements~~ based on the patterns of electrons in ~~the outermost energy level of~~ atoms*.
    - Lesson 7: Students use a mathematical model to examine Coulomb's law calculations and are asked "why would it be reasonable that for our investigations, there would be the same amount of negative charge as there is positive charge in the system? Students will say because we removed the electrons from one material and put them onto the other material" (Teacher Edition, page 166).
    - Lesson 8: Students use their paperclip models to "…individually model what they think happened to the atoms in the paper when the balloon was brought close to them. Prompt them to consider that the paper did not become charged the way the balloon did, but that the paper was attracted to the balloon—how can we model that with the paper clips? How can we show that the paper stood on end, but then fell back down as soon as we took the balloon away?" (Teacher Edition, page 181).
    - Lesson 11: Students complete a reading about the nature of how charges move through air and students are asked to "model what is happening to atoms in the air. Have another couple students representing air atoms bring their paper clip models over to the electric field under the cloud and remove an electron from those atoms. Say, so now we have some ionized air under the cloud" (Teacher Edition, page 228).
- **HS-PS1-3**: *Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles*.
    - Lesson 4: "Develop investigation questions with a partner. Say, But before we decide what data we want to collect and how we might go about producing static electricity, let's identify a question we want to answer. As you develop your investigation questions, be sure to consider if we have the materials you would need to investigate them and that we could investigate them in the classroom. Display slide D. Give students three minutes to turn and talk with a partner to discuss the prompts on the slide. Encourage students to record their responses in their science notebooks. After a few minutes, have students share these out as a class. Push students to articulate how the question they want to investigate is connected to the water dropper system." (Teacher Edition, page 98).
    - Lesson 5: Students complete a sticky tape investigation to examine interactions between different tapes and their relative stickiness. Teacher begins by introducing the investigation and saying "…let's use another investigation to help us gather more data to determine if our hypotheses are correct. Arrange students into pairs. Display slide B and distribute a copy of Sticky Tape Investigation to each group. Tell students to follow along as you set up the Sticky Tape Investigation using the directions on the slide" (Teacher Edition, page 116).

  - Lesson 7: Students investigate ways to measure force in systems with differing charges. Teacher says "…you and your group are assigned to test two different conditions. Due to the timing, you will test one condition today and one condition at the start of our next class. Tell students that the procedure for their additional condition is located on the reverse side of their handout. Distribute either Conditions 1 & 2 Procedures or Conditions 3 & 4 Procedures to each student, depending on their group's assignment. Give students three minutes to individually read the procedure for the condition they will test first (1 or 3). Elicit differences between these conditions. Students should recognize that Condition 1 has like-charged objects, while Conditions 3 has oppositely-charged objects" (Teacher Edition, page 159).
  - Lesson 13: Students "plan an investigation. Display slide I. Distribute a copy of Salt Investigation Plan to each student. Have students work in groups of five to outline their investigation design for part 1 and 2…carry out investigations. Monitor students as they carry out their investigations and record their observations" (Teacher Edition, page 261).
- **HS-PS2-4**: *Use mathematical representations of ~~Newton's Law of Gravitation and~~ Coulomb's Law to describe and predict the ~~gravitational and~~ electrostatic forces between objects*.
  - Lesson 7: Students are asked to apply their conceptual learning of Coulomb's Law to the mathematical model generated. Students are asked to "…think about how to work through the force calculation by hand. Direct students' attention to the 'Solving for force using Coulomb's law' poster. Then, work through all the steps on the poster, emphasizing the importance of each step: perform any necessary unit conversions to match the units in the given k-value (cm and e); substitute the known values and their units for the corresponding values in the equation and ensure that the order of operations is maintained; show any intermedia calculations you perform, such as the result of operations within parentheses, and record the corresponding units; show the final result of these calculations and the corresponding units" (Teacher Edition, page 168).
  - Lesson 7: Students apply their knowledge of Coulomb's Law. "Show how to use the Coulomb's law equation to predict the amount of force for the assigned values given in the Assigned Values for Predictions table. Document your solution steps in the space below" (Solving for Force, page 1).
  - Lesson 7: "How do our calculations from lightning compare to the forces we measured [using the water dropper]? Why is that? What do you think the difference in those forces means? How can you use what we figured out today to help explain what causes so much charge to move so quickly during a lightning strike?" (Teacher Edition, page 170).
  - Lesson 9: "Calculate the strength of force of attraction (N) for each mask, and use the calculated values to support your choice [of mask type]" (N95 Mid-unit Assessment, page 2).

- **HS-PS2-6**: *Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials*.

    - Lesson 12: "Display slide G. Say, I have a reading about lightning rods which may help us think about why sometimes metals seem to be safe and sometimes they are unsafe. We will use the connect, extent, question reading protocol to make sense of the reading. Use the information on slide G to explain how students should engage with the protocol. Remind students that if they encounter a new vocabulary word, they should make a note of it and add it to their personal glossaries. Distribute Lightning Rods and Connect, Extend, Question to students. Give students five minutes to read the article and complete Connect, Extend, Question. How does the information in this reading connect to the data and the safety tips we examined? How does this help us extend our thinking to be able to explain why some materials are safer than others when there is lightning?" (Teacher Edition, page 242).
    - Lesson 12: Students read about the structure and composition of lightning rods to highlight their ability to interact preferentially with electricity. This reading is connected to the provided handout that highlights differing structures before and after charges are applied. Students are encouraged to "examine the three atomic models of materials below. As you examine the models, consider: the similarities or differences in electron behavior in the three different materials, the different way that atoms, molecules, or ions are connected to one another" (Metals/Nonmetals Comparison Handout).
    - Lesson 14: As students develop their Gotta-Have-It Checklists, they are asked to consider the "components (pieces/objects in the system)," "interactions/relationships (connections between components)," and "mechanisms (how and why interactions lead to effects)" which require the identification of molecular- and/or atomic-level structures to clarify "why are some places safer than others when lightning strikes?" (Consensus Gotta-Have-It Checklist, page 2).
- **HS-PS3-2**: *Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).*
    - Lesson 10: Students generate models to "establish that energy stored in the field transfers to the particles when oppositely charged particles come together and that energy transfers from particles to the field when those same particles move apart" as they are asked "what caused there to be more energy stored in the field in the system? Where did the increased energy in the field come from? How did the energy transfer when the charged particles were move?" (Teacher Edition, pages 206–207).
    - Lesson 11: Students are asked to read a resource, Power of Lightning and "…they should record any new ideas in their notebooks that will help us think about connections between matter, energy, and forces" (Teacher Edition, page 230) and later, are asked to use that information to consider "how could we show energy transfer as light (radiation) with our energy transfer models? How could we show energy transfer as sound (thunder) with our energy transfer models?" (Teacher Edition, page 231).
    - Lesson 12: Students use the transfer of energy as a means to highlight conservation when discussing conductivity. Students are asked to examine models of lightning rods and consider "how do these models help explain why metals are good conductors and

wood is not? How do these models help explain why poor conductors get warm quickly when strong electric forces are applied to them? How do the reading and models work together to help you make sense of how lightning rods work?" (Teacher Edition, page 245).

- **HS-PS3-5**: *Develop and use a model of two objects interacting through electric ~~or magnetic~~ fields to illustrate the forces between objects and the changes in energy of the objects due to this interaction.*
  - Lesson 6: Students read about "How Lightning Starts" and are asked to consider "what information did you get from the article to answer our question? What static interactions are happening in the sky, according to the reading? Where are the electrons coming from that are causing these static interactions?" (Teacher Edition, page 142).
  - Lesson 8: Student ideas about attraction between objects after working with the simulation are used to spur further conversation as teachers are asked to "Have students individually model what they think happened to the atoms in the paper when the balloon was brought close to them. Prompt them to consider that the paper clip did not become charged the way the balloon did, but that the paper was attracted to the balloon—how can we model that with the paper clips? How can we show that the paper stood on end, but then fell back down as soon as we took the balloon away?" (Teacher Edition, page 181).
  - Lesson 10: Students are asked to "look at your results for opposite charges and compare them to the result for like charges. What differences do you see? What general rules could we make about when there is a lot of energy stored in the field? Why is this important to consider when examining how lightning interacts with materials?" (Teacher Edition, page 209).

Suggestions for Improvement

None

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 because only DCIs from the physical science domain are used to support student sense-making related to the central phenomenon. CCCs are used at grade-appropriate levels to support student sense-making during the unit, although their usefulness across science domains is not made explicit to students.

Grade appropriate elements of both **PS1.A** and **PS2.B** are used to make sense of the phenomenon and solve the anchoring problem. For example:

- Lesson 9: In the mid-unit assessment, Static Interactions Assessment, students use both **PS1.A** (atomic structure) and mathematical representations derived from **PS2.B** (Coulomb's Law) as students attempt to provide evidence of their integration of knowledge of atomic structure and the nature of charge relationships that exist at that scale.
- Lesson 12: "Compare models of lightning rods. Explain that students will have two versions of a lightning rod model to evaluate. Distribute Model Comparison and display slide N. Say, We have seen how electricity could move through metals, now let's apply those ideas to lightning rods. Have students copy the table shown on the slide into their science notebook. Tell students to use any information from this lesson to help them identify the merits and limitations of each model. Then have them develop an explanation for how the atomic level structure of lightning rods allows them to function to protect buildings" (Teacher Edition, page 246).
- Lesson 13: "Introduce ionic compounds. Say, So salt does not conduct when it's solid, and we think that is because the positive and negative neutralize each other. But when it dissolves it splits up? Display slide T. Tell students that since salt is a substance made of these ions, it is called an ionic compound, and that the sodium and chlorine are held together by what is called an ionic bond. Remind students that in Lesson 12 they saw some examples of bonds in the models and that this is another example. Suggest students pause here and add ionic bond and ionic compound to their personal glossaries" (Teacher Edition, page 266).

In the "Where We Are Going" section in each lesson, there are references to how the CCC elements have been developed and used in other disciplines. However, it is not clear that students are made aware of these connections. Related evidence includes:

- Lesson 3: The teacher is told "For CCC: 3.2: Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students already have experience examining systems indirectly, due to unmanageable time scales, from OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)" (Teacher Edition, page 77).
- Lesson 7: The teacher is told "Students will also consider the role of scale in the effects of Coulomb's law for the first time in this course (CCC: 3.1) and use algebraic thinking to predict the effects of changes in one variable (CCC: 3.5). Build on students' use of scale in OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit) and knowledge from Polar Ice Unit by eliciting thinking about the effects of changes in more familiar variables, like carbon dioxide and temperature, and mapping them to the variables used in this investigation" (Teacher Edition, page 152).
- Lesson 12: The teacher is told "Students use the crosscutting concept structure and function (CCC: 6.1). In middle school students developed understandings around the relationship of structure and function in One-way Mirror Unit, Cup Design Unit, and Collisions Unit. This lesson is students' first experience using structure and function in OpenSciEd High School Chemistry. Students continue to use this crosscutting concept throughout OpenSciEd Unit C.3: How could we find and use the resources we need to live beyond Earth? (Space Survival Unit) as they finalize the atomic model" (Teacher Edition, page 258)

Suggestions for Improvement

Consider providing discussion prompts that give students opportunities to consider how CCCs can be useful for sense-making in multiple scientific disciplines. This could include disciplines in prior units.

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 CCSS connections are explicitly stated in the unit for both ELA and Mathematics. Students use reading skills to develop understanding and explanations of scientific concepts, phenomena, or results of investigations. Students use writing skills to explain and communicate their understanding and have opportunities for speaking and listening in the classroom. In addition, the expected literacy skills are not above grade level.

The materials claim the following CCSS ELA connections:

- **CCSS.ELA-LITERACY.RST.9-10.10**: *By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.*
  - Lesson 1: Students are presented multiple case studies and sources of data, "Prepare to read. Display slide E. Divide the class into groups of three and ensure that a member of each group is assigned on(sic) of three readings or video. Lightning stories: mythology; lightning stories: inventors; [link]" and later, "Analyze data in graphs of lightning flashes versus time. Display slide G which includes: the graphs also shown below. Direct students to draw a horizontal line under the text they already have in their Notice and Wonder chart to indicate that we are now gathering ideas from a different source" (Teacher Edition, page 37).
- **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*.
  - Lesson 4: Students read about forces at a distance and are asked "what did the reading tell us about the force behind static electricity? What is charge and how does it relate to the electrostatic force? What are field and how do they relate to the electrostatic force?" and later, "ask students where we might add charges and fields in our initial model or Lesson 3 models…update the M-E-F poster…last lesson we added forces to this triangle, but we were not sure how it connected to other ideas. Let's focus on their matter-force connection. Draw a line between the two, as shown, then ask: where do the forces come from? They are related to matter, but how specifically?" (Teacher Edition, page 106)
  - Lesson 5: Students incorporate text and information from a simulation to develop understanding around atomic structure.
  - Lesson 6: Students investigate static interactions using pieces of sticky tape. They relate these interactions to a reading about how lightning forms in clouds and think about contradictions between the data and reading to think more deeply about scale.
- **CCSS.ELA-LITERACY.RST.9-10.8**: *Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.*
  - Lesson 11: "Consider how headlines can be misleading. Display slide I. Say, in a moment you will work in small groups to research how electrons can move through air to form lightning. Earlier, I was researching lightning formation. I found an article in a magazine published pretty recently titled 'Detailed footage finally reveals what triggers lightning,' and I was so excited thinking that scientists had figured it out! Then I read the original paper by the researchers who did this work and learned that yes, they were able to gather data that previously had been difficult or impossible to get, but that did not mean they knew exactly what was happening. You have probably encountered similar issues in English classes or online. What can we take away from that?" (Teacher Edition, page 225).

- Lesson 13: "Investigate claims about lightning safety based on the geese phenomenon. Display slide LL. While handing out Lightning Safety Claims to students, say, if lightning can kill a flock of geese sitting on a river in less than a second, it makes sense that there are so many precautions we hear lightning let's use our knowledge to evaluate whether or not these claims about lightning safety are fully accurate. Instruct students on how to evaluate claims. Read through the instructions to Lightning Safety Claims as a class. Be sure to point out each column and what needs to be included in each, and let students know if you plan to collect these as an assessment or not. Give students 8 minutes to work independently on the handout" (Teacher Edition, page 275).

- **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.*
    - Lesson 11: "Consider how we could represent those energy transfers. Display slide T and discuss the prompts with students…How could we show energy transfer as light (radiation) with our energy transfer models? How could we show energy transfer as sound (thunder) with our energy transfer models? How could we show energy transfer to make nitrates with our energy transfer models?" (Teacher Edition, page 232).

The materials claim the following CCSS Mathematical connections:

- **CCSS.MATH.CONTENT.HSA.REI.A.1**: *Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.*
    - Lesson 7: Students "orient to an equation-based mathematical model of our system. Gather students in a Scientists Circle and display slide N. Say, this equation is one proposed model scientists have developed for some of the relationships we identified. It is a little more complicated than what we saw in Polar Ice Unit, but is pretty similar for some equations you have seen in math class. Let's identify the variables in this equation. Have students locate this equation on their copy of Comparing Forces Relationship" (Teacher Edition, page 161).
    - Lesson 9: Students answer a question asking "if the kid rubbed the balloon for 30 seconds, resulting in a charge of 2.809×10^{12} e, and the charge of the can was -2.467×10^{10} e, use Columb's law to predict the actual value of the force of attraction between that balloon and the can that is 10 cm away" (Static Interactions Assessment, pages 3–4).
- **CCSS.MATH.CONTENT.HS.N-Q.1**: *Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; ~~choose and interpret the scale and the origin in graphs and data displays.~~*
    - Lesson 7: Students are asked to apply their conceptual learning of Coulomb's Law to the mathematical model generated. Students are asked to "…think about how to work through the force calculation by hand. Direct students' attention to the 'Solving for force using Coulomb's law' poster. Then, work through all the steps on the poster, emphasizing the importance of each step: perform any necessary unit conversions to

match the units in the given k-value (cm and e); substitute the known values and their units for the corresponding values in the equation and ensure that the order of operations is maintained; show any intermedia calculations you perform, such as the result of operations within parentheses, and record the corresponding units; show the final result of these calculations and the corresponding units" (Teacher Edition, page 168).

  - Lesson 13: Students are asked to "discuss how the new ideas apply to the Geese Lightning Strike phenomenon. Display slide KK. Call on a few students to share their explanation of how the geese died with the class. Direct students to consider the three additional prompts on the slide as the ideas about water, salinity, and conductivity are mentioned in their explanation. Give students some independent thinking time to consider the prompts before sharing, if it seems necessary. However, keep the class discussion to two minutes. What range do you think the salinity was of the St. Lawrence River? What evidence do we now have to support the idea that the lightning strike produced some type of charge flow through the birds? Could the same thing happen to other animals in the water as well?" with potential student responses including "A river is usually fresh water, so it could be similar to the Great Lakes' salinity, or around 0.05–0.06. It connects the Great Lakes and the Atlantic Ocean, so it might have a salinity between that of the lakes and the ocean, so between 1.0 and 3.0" (Teacher Edition, page 275).

Activities that involve readings provide grade-appropriate texts and protocols for reading the texts to develop understanding and explanations of the science concepts and phenomena, although at times, the allotted time may not be long enough for all students to complete the task. For example:

- Lesson 1: Students are given five minutes to read their assigned story or watch the video. This time includes recording their answers to the two questions on the slide (Teacher Edition, page 37). The stories are short enough that many students will be able to accomplish both the reading and writing task within the five minutes. However, there may be some students who are not able to accomplish the writing task before the end of the five minutes, especially those who are viewing the video, since it is two minutes and 21 seconds and answering the questions may require reviewing portions of the video again.
- Lesson 4: Students use a Coherent Reading Protocol to connect the *Distance Forces* reading to their experiments and discuss how it extends their thinking with new information. An Attending Equity callout explains that "The reading has been broken down into three chunks of text" (Teacher Edition, page 106), and that this will help students make sense of the text and support multilingual learners.
- Lesson 5: Students are provided a protocol to read "Structure of Matter" in pairs, with one person reading the first two sections, and another the last two sections, and then they share the central ideas they identified for each chunk of text (Teacher Edition, pages 118–120). Although the meaning of relative mass is embedded within the reading, students may not pick up on this embedded comprehension text, and evidence was not found that assistance is provided such

that students will be able to fully comprehend the relative mass numbers and what they represent.

- Lesson 6: Students read an article that summarizes text written by scientists titled *How Lightning Strikes* (Teacher Edition, pages 141–142; *How Lightning Strikes* pages 1–4).

Suggestions for Improvement

- In Lesson 1 when student groups are completing the readings or viewing the video before answering questions from the slide, consider having the class groups read over the questions before the five-minute time begins for reading/viewing and writing. Also consider providing teacher instructions for supporting students who might find it challenging to answer the questions before the time is up so that they can return to their group and fully share the story they engaged in.
- In Lesson 5, students encounter the phrase “relative mass,” which is required to comprehend the differences in mass between protons, neutrons, and electrons. In spite of this support, students may require more context or understanding to use that vocabulary word to make meaning of the text. Consider providing students with an opportunity to distinguish relative mass from a more absolute mass that could be determined for each of those subatomic particles. Alternatively, consider using alternative phrasing to illustrate the intended idea that an electron is approximately 2,000 times less massive than a proton or neutron.
- In Lesson 5, in order to assist comprehension of the relative mass numbers in the article that students use to fill out the Atomic Structure classroom poster, consider including a brief discussion of the term as students discuss the central ideas of the reading.

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. In the unit, students experience phenomena as directly as possible with media representations when firsthand experience is not appropriate. Students have multiple opportunities to connect the phenomena they figure out to their own prior experiences, community, or culture. Opportunities are also provided for students to connect their explanation of a phenomenon to questions from their own experiences.

The phenomena students encounter for the unit and within the lessons are engaging. Students experience the phenomena as directly as possible through firsthand or media representations. Related evidence includes:

- Lesson 1: "The phenomenon that we will explore in this unit is one you have probably all witnessed yourselves, but I have a video here to watch so we can all have an example to be thinking about" (Teacher Edition, page 34).
- Lesson 1: Students view videos of lightning strikes in real time and in slow motion and are given the opportunity to repeat the videos in order to carefully observe the lightning phenomena and generate questions (Teacher Edition, pages 34–35). The lightning videos are engaging and can be viewed repeatedly with students noticing new aspects of the phenomenon each time. The materials suggest that "If your area recently experienced a storm with lightning, use that as a way to introduce the unit. You could say something like, After last night's storm, I was really wondering about lightning and why it happens with storms…" (Teacher Edition, page 34).
- Lesson 2: "Elicit any new ideas for investigations or questions that students have after talking with their families. Record these in the appropriate places" (Teacher Edition, page 61).
- Lesson 3: "The water dropper will likely be a surprising phenomenon for students. As home learning, you may wish to have them share their experience with family or community members

and ask them for suggestions for different objects they would be interested in seeing detected for static effects" (Teacher Edition, page 89).

- Lesson 4: An Attending to Equity callout states "Experiential learning, such as feeling the presence of static or experiencing a light shock, brings students close to phenomena in a relatable and memorable way" (Teacher Edition, page 97), thus supporting the idea of experiencing phenomena as directly as possible.

Students have some opportunities to relate the phenomenon and problem to their own lives. Related evidence includes:

- Lesson 1: "Elicit students' lightning stories. Display slide D. Give students one minute to turn and talk with a partner or table group. Then ask for several volunteers to share their own stories or stories from their partner." Students continue to discuss "what stories, family history, or mythology have you heard about lightning?" (Teacher Edition, page 36).
- Lesson 1: Teachers are encouraged to supplement the readings and videos in the section with any others that "are centered on the cultures and experiences of students in the classroom or provide an extended foundational experience to students who have experienced lightning only infrequently" and a YouTube example is provided which highlights a Navajo elder who is also quoted in Lesson 11 (Teacher Edition, page 36). The materials state that "the goal of this activity is not to provide students with information about the mechanisms of lightning but instead to inspire students to think about how people, including those in their community, have viewed and continue to think about lightning" (Teacher Edition, page 36).
- Lesson 1: Students use their own experiences in a discussion. "Brainstorm examples of related phenomena and safety precautions. Display slide Z. Say, We have already been mentioning some of our personal experiences with lightning and connected ideas, but now we want to take time to think about and record these specific ideas that we can use in this unit. Have students turn and talk with a partner about the prompts on the slide, also listed below: When and where have you experienced (or seen someone experiencing): lightning? something similar to lightning? What signals do you use to decide to protect yourself against a storm? How does where you are determine how you stay safe?" (Teacher Edition, page 51).
- Lesson 2: "Close out class and tell students that tomorrow they will have an opportunity to pursue some of their ideas for investigating the water dropper system. Encourage students to bring in objects they would like to test with the water dropper next class" (Teacher Edition, page 72).
- Lesson 3: Students investigate using their own objects before the investigation with the pre-determined objects from the lesson materials. A teacher note states, "Allowing and encouraging students to bring in or choose objects to test with the water dropper system supports student engagement. Increasing student voice can make investigations feel more relevant and engaging to students" (Teacher Edition, page 80). At the end of the lesson, students are given the opportunity to again bring some of their own supplies to the next class to use as they investigate static (Teacher Edition, page 89).
- Lesson 5: "We have many experiences of electrostatic interaction in our everyday lives. What is one example where you experienced static electricity? Describe what you think is happening to

the subatomic particles of the atoms in the objects that lead to the interactions you saw, and use the reading, simulation, and models from class to support your explanation" (Exit Ticket, page 3).

- Lesson 8: "Extension opportunity: Provide balloons and/or paperclip models for students to take home so that they can demonstrate the phenomenon from this lesson, as well as Coulomb's law, to their families. Have them report back at the start of Lesson 9" (Teacher Edition, page 185).
- Lesson 11: "Have you experienced, heard stories, or seen videos of situations where there was a large amount of energy transferred? What did you experience/see/hear?" (Exit Ticket, page 2).
- Lesson 12: The teacher asks the students to, "Think about a time when you had to shelter during a lightning storm. Use the prompts on the slide to write about that time" (Teacher Edition, page 239). They share their responses to questions such as "Where were you?" and "Where did you go?" (Teacher Edition, page 240) while others show a thumbs up or snap their fingers if they have the same idea on their paper. An Attending to Equity callout states, "The goal of having students reflect on a time they have had to take shelter is to support engagement by increasing the relevance for students as they consider what contributed to making the shelter safe or unsafe" (Teacher Edition, page 239). Connecting to student experience provides relevance so students can connect to why their learning may be important in their own lives.
- Lesson 12: "Alternatively, have students share their explanations with their families as home learning, and return to class with additional ideas about what people should do to stay safe in storms" (Teacher Edition, page 249).

Suggestions for Improvement

In the section of Lesson 1 when the optional activity for reviewing scientific modeling using the action of kicking a ball is suggested, consider including a suggestion to the teacher to connect with the experience of any soccer players in the classroom or student awareness of the regional professional soccer team in order to increase relevance to student experiences.

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 because the materials provide 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.

Students are supported to express their ideas in a variety of ways in the unit. There are many opportunities for students to express their ideas through different kinds of discussions. Students sometimes express their ideas in written form. Related evidence includes:

- Lesson 1: "Reinforce that students have multiple options for expressing their ideas. Encourage the use of gestures, especially as students describe their ideas about the direction, motion, branching, etc. of the lightning. Invite students to point at places on the screen during discussions. 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" (Teacher Edition, page 35).
- Lesson 1: A teacher margin callout states, "Encourage student-to-student talk with a focus on raising questions, clarifying, or adding on to what someone has said, rather than a focus on debating or arguing. Students might also use head nods or hand signals to show they had a similar idea to a classmate's" (Teacher Edition, page 35).
- Lesson 1: Students express their ideas about lightning based on viewing videos and their personal experiences (Teacher Edition, page 34). Later in the unit, students provide evidence to support their ideas (Teacher Edition, page 42).
- Lesson 1: The class starts to develop a consensus model. "Facilitate a Consensus Discussion while you record the class's initial consensus model on a piece of chart paper or shared digital space titled, 'What causes lightning to strike at a particular place and time?'" (Teacher Edition, page 49).
- Lesson 4: "Display slide D. Give students three minutes to turn and talk with a partner to discuss the prompts on the slide. Encourage students to record their responses in their science notebooks. After a few minutes, have students share these out as a class. Push students to articulate how the question they want to investigate is connected to the water dropper system" (Teacher Edition, page 98).
- Lesson 5: "The purpose of this discussion is to build students' ideas about what is most important from what they have learned about subatomic particles so far. As students share,

press them to support their ideas using their understanding of the different experiments discussed in the reading. It is not necessary for the class to reach a consensus at this point. They will have the opportunity to return to their ideas and work toward consensus later in this lesson" (Teacher Edition, page 119).

- Lesson 5: "Participate in a roundtable discussion. Display slide S. Say, Let's share what we figured out about how the paper clip models can help us explain what we saw in the sticky tape investigation. Choose one group to demonstrate their models, and have them stand so all students in the Scientists Circle can see the demonstration. Ask the group to demonstrate their paper clip models for the four observations they modeled on slide Q. Record student ideas to the final prompt, not shown on the slide, on a sheet of chart paper" (Teacher Edition, page 126).
- Lesson 5: Students use a Discussion Mapping Tool to record which students are offering ideas during a scientist's circle discussion. The teacher is given specific instructions for times during the discussion in which to have a new volunteer use the mapping tool, and later in the discussion, students reflect on what the discussion map shows when projected, and decide on some things they should consider in future discussions, such as "We should invite people into the discussion who have not had chances to add to the discussion" (Teacher Edition, pages 129–130).
- Lesson 5: Students complete an Exit Ticket to express their individual understanding of atomic structure and static electricity (Teacher Edition, page 131).
- Lesson 7: Student groups record their responses to questions posed about an investigation (Teacher Edition, page 167).
- Lesson 11: After classroom experiences, students develop their own definitions of science words. "Update Personal Glossaries. Display slide H. Have students take a moment to add 'insulator' and 'conductor' to their personal glossaries. Possible entries may look like: insulator—a substance that electrons cannot easily move through. conductor— a substance that electrons can easily move through" (Teacher Edition, page 224).

Students have numerous opportunities to use feedback from the teacher and peers to reflect on and change their thinking. Related evidence includes:

- Lesson 1: Students create initial models depicting how lightning forms and a strike occurs. Later, following a discussion on energy and matter, students "Revise models to include matter and energy. Display slide T. Say, Now that we have thought about what lightning is, let's see if we can revise our models to show where we think matter and energy are and what they are doing. Tell students to work with a partner to think about how to specifically model the matter changes and energy transfer involved. Suggest that students spend two minutes individually revising their models to include matter, and another two minutes revising them to include energy. Ensure that students are not just adding these components, but drawing relationships to other parts of the system" (Teacher Edition, page 46).
- Lesson 1: "After the discussion, collect models so that you can provide individual feedback to students. In this feedback, ask questions to encourage students to be more explicit in their models and use of evidence, and to incorporate particular patterns across scales into their

explanations. However, do not correct their thinking about scientific concepts" (Teacher Edition, page 51).

- Lesson 3: "The end of this lesson may be an opportunity for students to self-assess given what they have figured out so far. Such self-assessment could prepare them to give better peer feedback in Lesson 4. A standard template for self-assessment may be found in the OpenSciEd Teacher Handbook: High School Science" (Teacher Edition, page 89).
- Lesson 4: "Prepare students to give each other feedback. Display slide B. Explain that scientists often use feedback to sharpen their ideas. Reference the Community Agreements and tell students that in this lesson we will focus on being committed to our community. Highlight particular agreement language that emphasizes that part of being in a community is providing honest, constructive feedback to one another. Remind them that the goal is for everyone's ideas to be pushed a little bit, so that we can make more progress as a class" (Teacher Edition, page 98).
- Lesson 4: Students use data collected from the water dropper system investigation to "revise Lesson 3 models to account for attraction and repulsion in the system. Display slide M. Ask student to do the following: 1. Revise their models based on peer and teacher feedback and empirical evidence from the investigations. 2. Explain how they used evidence, including empirical evidence from the investigations, to revise their model" (Teacher Edition, page 103).
- Lesson 7: "Collect Solving for Force and provide feedback as students prepare for the mid-unit, summative task in Lesson 9. If students do not document solution steps in the first part of this handout, or report that they have answers different from those expected when comparing with their partner, then give them an opportunity to practice these skills again as home learning, this time with all values doubled" (Teacher Edition, page 169).
- Lesson 8: "As students model polarization, make sure students can distinguish verbally, or with their model, that this is different from ionization. Be prepared to address misconceptions or partial understandings, such as students fully removing paper clips when they represent what happens to the ground during a lightning strike. If students seem confused, prompt them to think about what happens after the lightning strike, or ask them to recall that the paper scraps were not attracted to other objects after the balloon was removed" (Teacher Edition, page 171).
- Lesson 9: "Instead of collecting students' models for feedback in this lesson, have them exchange models with a partner or take their model and Gotta-Have-It checklist home in order to receive outside feedback. You may then collect students' models and provide feedback along with feedback on the mid-unit assessment" (Teacher Edition, page 193).
- Lesson 9: Students complete "Modeling Reflection" where they document how their thinking has changed over time by comparing their initial and revised models. "Showing the relationships between different components in a model, I used to... Now I..." (Lesson 9 Handout Modeling Reflections).
- Lesson 10: "Revise the M-E-F poster. Display slide L and the M-E-F poster. Say, We have figured out a lot of important ideas in this class! Then ask about the prompt on slide L. Give students a minute to turn and talk if they struggle to respond. Listen for the following ideas: Energy is stored in the field. The field comes from charges, or charged matter. The field that stores energy is the field that causes forces. We know there is energy in the system when the particles are

moving or move after being released. Energy transfers between the field and the particles" (Teacher Edition, page 209).

- Lesson 10: "Update and revise lightning models with takeaways from Day 1 and self-assessment. Say, Yesterday, we learned more about where the energy in lightning comes from when charged objects interact. Today, we looked at the models we made before we figured those things out. We can put all of that together in a revised model that shows your most up-to-date understanding of how lightning works" (Teacher Edition, page 213).
- Lesson 14: Students use a class-generated checklist to provide feedback to classmates' models. "1. Stand around a model. 2. The developer shares their work with the rest of the group. 3. The rest of the group members provide written peer feedback. 4. Rotate to a new model and repeat steps 1–3" (Lesson 14 Slides, Slide H).
- Lesson 14: "Individually revise models based on feedback. Display slide I. Have students return to the partner they brainstormed the Gotta-Have-It Checklist with, review their feedback, and then update their models based on that feedback" (Teacher Edition, page 288).

Suggestions for Improvement

None

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials identify and build on students' prior learning in all three dimensions because teacher guidance documents include student learning outcomes at the element level for each lesson and those pieces of information can be used to inform the prior knowledge required for subsequent lessons within the unit. The unit materials clearly outline expected prior learning students should have with all elements as well as supports for clarifying potential alternate conceptions. However, as written, teachers may not be able to quickly determine the prior student learning required for a given lesson. It also may not be evident to teachers how the SEP and CCC element level learning outcomes from one lesson lead to the learning outcomes of the next lesson.

Related evidence includes:

- The Unit Overview summarizes how learning will build through the unit.
  - SEP: "Because of lightning's complexity as a phenomenon and reliance on microscopic explanations, developing and using models is intentionally developed across the unit, beginning in Lesson 1 as students are supported in developing initial models using matter and energy lenses that are familiar from Polar Ice Unit. Students have the opportunity to move between models in Lesson 2, use a model to generate data in Lesson 3, and design tests of and revise their own models (based on new evidence and peer feedback) in Lesson 4. This work builds an initial understanding of attractive and repulsive forces at a distance. In Lesson 5 they are introduced to the paper clip model to support their thinking about atomic structure. Through Lessons 8, 9, and 10, they continue to work with multiple types of models and revise their own models with increasing levels of independence using reflection and feedback. In Lessons 12 and 13 they evaluate the merits and limitations of particularly complex atomic-level models, and in Lesson 14 develop, receive feedback on, and revise individual models based on the unit's evidence and peer feedback" (Teacher Edition, page 15).
  - CCC: "As students move between the microscopic and lightning scales, scale, proportion, and quantity is also intentionally developed across the unit. In Lesson 1 they examine patterns across time scales. However, to explain patterns in when and where lightning strikes, they must examine lightning indirectly with smaller-scale investigations and models in Lessons 3 and 5. Orders of magnitude helps students move across the massive variation in scale in Lesson 6. Lesson 7 pushes students to quantify their thinking around Coulomb's Law and quantify its impact on the lightning phenomenon. In Lesson 8 they figure out that patterns are different at different scales as induced polarization occurs in the ground preceding lightning. In Lesson 10 they consider the significance and cause of the large energy scales associated with lightning, and in Lesson 14 they again examine patterns across different scales through modeling materials that have differing properties due to force interactions" (Teacher Edition, page 15).
- Unit Overview: "It is valuable to think of ideas like these [e.g., lightning never strikes the same place twice] not as misconceptions that need to be replaced but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. This unit intentionally addresses several of these alternate conceptions. Lessons 7–9 and 11 provide evidence that lightning tends to strike taller objects, but will not necessarily do so. Lesson 12 provides an extension opportunity for students to think about how lightning rods really protect buildings and whether rubber can affect other objects, and Lesson 13 includes guidance on supporting students' thinking around whether water attracts lightning or is so conductive that electricity will easily reach and shock objects in it" (Teacher Edition, page 21).
- Lesson 1: "Students might come into this unit with several partial understandings of what lightning is and what causes it, such as that lightning never strikes the same place twice, lightning always strikes the tallest objects, it is good to stand under a tree during a

thunderstorm, rubber tires on a vehicle are what makes it safe if struck by lightning, etc. This lesson is not the place to correct these ideas. Students will explore the static interactions that cause lightning and why certain places are safer than others through their own investigations during the unit" (Teacher Edition, page 33).

- Lesson 1: The materials state that if students experienced OpenSciEd Unit B.2 about fires in ecosystems, they would bring a wealth of information about the relationship of lightning to wildfires that can be built upon during the lesson (Teacher Edition, page 42).
- Lesson 1: While introducing the stories about lightning that the students will read, the teacher points out that "even though people do not always use these terms, many of the stories involve matter and energy playing special roles, just like they did throughout our first unit" (Teacher Edition, page 36). This instruction connects student learning about energy and matter to what they learned in the prior unit, thus helping them to see that they will be building on this prior knowledge.
- Lesson 2: "In Lesson 1, students developed an initial consensus model to explain how lightning formed. In this lesson, students identify key components in this model to determine that the role of rain is a point of confusion. They use data and a physical model to decide that rain not only correlates with lightning, but could be a cause (CCC: 2.1). In doing so, students move between a pencil-and-paper model (the initial consensus model) and a physical model (the water dropper system) and consider the relative merits and limitations of each (SEP: 2.4). Before moving on, students should have questions about the water dropper system and ideas about how to investigate these questions" (Teacher Edition, page 60).
- Lesson 2: A teacher note explains that students should recognize "that different materials have different properties, established in OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit) in middle school" (Teacher Edition, page 68). Then teachers are provided with a strategy to use with students to use reasoning to connect that learning about categories of properties with the sorting of materials activity in this lesson.
- Lesson 3: The materials state, "Students should be familiar with distance forces from middle school (formally) and everyday life (informally). If students struggle where to begin their revised models, elicit ideas about where else we see objects push or pull one another when they are not touching" (Teacher Edition, page 82).
- Lesson 4: "The focus of this lesson is looking for patterns in observed interactions between objects and in what students do to cause the observed interactions. Students will notice that many objects display static interactions, either attractions or repulsions, after rubbing or friction is generated with at least one of the objects. In middle school, students identify patterns that help them explain systems, and realize that macroscopic patterns can relate to microscopic and even smaller-scale structures. In Lesson 1 they identified patterns with an intention of identifying causality. Here, students establish that empirical evidence is often needed to identify patterns (CCC: 1.5)" (Teacher Edition, page 96).
- Lesson 4: The materials state that students should be familiar with fields from the Magnets Unit, and then provide ideas for what the teacher can do to build on the prior learning if students are confused by the concept (Teacher Edition, page 104).

- Lesson 6: "This lesson builds on the middle school understanding that attractive and repulsive forces can act across distances (MS PS2.B), developed in OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit). In this lesson, students apply what they have figured out about what causes static interactions (the dislodging of electrons and separation of those pieces of matter) inside the common real-world phenomenon of lightning (HS PS2.B). Students also leverage prior understandings about convection's role in storms, developed in OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit) and re-addressed in OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit). Students continue to develop the focal science and engineering practice of obtaining, evaluating, and communicating information, particularly reading scientific text. The scientific literature related to lightning is mainly outside the scope of NGSS. While students will read scientific literature adapted for classroom use (HS SEP 8.1), much of the research on lightning goes far beyond electron transfer and kinetic and potential energy" (Teacher Edition, page 138).
- Lesson 10: "In OpenSciEd, we intentionally avoid trying to list or name different 'types' or 'kinds' of energy. Instead, students focus on where the energy is stored—in the movement of particles/objects or in a field—and how it transfers. This lesson also marks a shift in terminology from what students might be familiar with. The term 'potential energy' tends to make students think that it is energy that could exist or is not real and obscures the mechanism by which energy is stored. For this reason, after students have established where the potential energy is (in the electric field; that is, the space between the charges), we encourage use of the term 'energy in the field'" (Teacher Edition, page 203).
- Lesson 11: An Additional Guidance teacher note describes what students should already know if they experienced prior OpenSciEd units. "Slide D contains supplemental information about the composition of air. If students experienced OpenSciEd Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit) and OpenSciEd Unit 7.6: How do changes in Earth's system impact our communities and what can we do about it? (Droughts and Floods Unit), they should know that air contains oxygen and carbon dioxide. In Lesson 3 of Polar Ice Unit, students examined the composition of Earth's atmosphere" (Teacher Edition, page 223). A Supporting Students callout explains that in this lesson "Students may be familiar with different 'types' or 'kinds' of energy from middle school. However, in this lesson [students] are reintroduced to several manifestations of energy (thermal energy, light, and sound) as being related to particle motion, which in turn is begun because of energy stored in fields. Students spent much of Polar Ice Unit thinking about thermal energy, but have not named it as such in this course" (Teacher Edition, page 231).

Each lesson includes a Where We Are Going and NOT Going section that often includes information that usually identifies prior student learning in at least two of the three dimensions in the lesson, and cumulatively addresses prior learning in all three dimensions. The following are representative examples of the type of prior learning that is described for each lesson:

- Lesson 3: The materials explain prior learning for DCI element **PS2.B.2:** "The idea of attractive/repulsive forces and forces at a distance build on students' work with distance forces in middle school in OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit). Students may not distinguish these forces as different from magnetic ones. Students may also make reference to static or static electricity, though they may not equate either with electricity produced by a battery or in the wires of devices we plug into the wall. Both of these misconceptions are okay for now, as they will be addressed in later lessons" (Teacher Edition, page 77).

- Lesson 3: The materials explain prior learning for SEP element **2.6**: "Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. Students will use mathematical and computational models to solve problems in OpenSciEd Unit C.4: Why are oysters dying, and how can we use chemistry to protect them? (Oysters Unit)" (Teacher Edition, page 77).
- Lesson 3: The materials explain prior learning for CCC element **3.2**: "Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students already have experience examining systems indirectly, due to unmanageable time scales, from OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)" (Teacher Edition, page 77).
- Lesson 4: "Students may or may not come into this unit or lesson with a preexisting concept of charge or of opposite charges attracting. Until students have engaged with the readings in Lessons 4 and 5, probe these ideas. Push students to be more specific about what they mean by 'charge.' Emphasize that we need direct or trusted indirect evidence from investigations or observations (empirical evidence) in order to be sure how charge applies to lightning and other phenomena" (Teacher Edition, page 96).
- Lesson 5: "Previously, students developed understanding around obtaining, evaluating, and communicating information in OpenSciEd High School biology in Genetics Unit and Speciation Unit. This is also the first time in the OpenSciEd High School chemistry course that students engage with portions of SEP element 8.2. Students continue to develop this element in later lessons and future chemistry units as they work to synthesize information from various sources to develop and revise models and explanations (in OpenSciEd Unit C.3: How could we find and use the resources we need to live beyond Earth? (Space Survival Unit)), as well as solve problems (in OpenSciEd Unit C.4: Why are oysters dying, and how can we use chemistry to protect them? (Oysters Unit)). They do not use it to solve problems in this lesson" (Teacher Edition, page 114).
- Lesson 6: "In middle school, students connect macroscopic patterns to the nature of microscopic patterns (MS CCC 1.1). One intentionally developed crosscutting concept for this unit is Scale, Proportion, and Quantity, and this lesson builds on the element (HS CCC 3.4) that order of magnitude can be used to understand how a model at one scale (the water dropper) relates to a model at another scale (lightning). Students connect the atomic patterns of static electricity they figured out in Lesson 5 to the large-scale lightning system" (Teacher Edition, page 138).
- Lesson 7: The materials explain that "This lesson is designed to coherently build new ideas related to the following disciplinary core idea: PS2.B.1 Types of Interactions: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.... Students

enter this lesson with significant mathematical experience from OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit). This will support their thinking around SEP: 5.2 and SEP: 6.1 as they predict, graph, and describe the relationships among distance, charge, and force. Students will likely predict linear relationships based on their prior experiences, but will figure out later in the lesson that the relationship between force and distance is nonlinear. This is the first nonlinear relationship students will encounter in this course. You may wish to add it to the Mathematical Anchor Chart from Polar Ice Unit as an example. In any case, this prior tool may be useful to display to students throughout the lesson" (Teacher Edition, page 152).

- Lesson 8: The materials explain that this lesson is the first engagement of students with the DCI element **PS1.A.3** in this unit. The materials identify prior learning for the element. "This lesson continues building on the ideas of attraction between objects at a distance that students have been building across several lessons. In middle school, students relate observed macroscopic patterns of forces at a distance to related microscopic patterns" (Teacher Edition, page 176). The materials continue to describe how the learning will be built upon.
- Lesson 9: "In this lesson, students leverage the crosscutting concept of Energy and Matter for the first time in this unit, since it was intentionally developed in Polar Ice Unit. They consider matter flows throughout the lightning system (CCC: 5.2), with an emphasis on electron movement, as they develop their models. They engage partially in this 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. Energy flow is emphasized in Lesson 10, and transfer in and out of the system was addressed in the prior unit" (Teacher Edition, page 190).
- Lesson 12: "Students use the crosscutting concept structure and function (CCC: 6.1). In middle school students developed understandings around the relationship of structure and function in One-way Mirror Unit, Cup Design Unit, and Collisions Unit. This lesson is students' first experience using structure and function in OpenSciEd High School Chemistry. Students continue to use this crosscutting concept throughout OpenSciEd Unit C.3: How could we find and use the resources we need to live beyond Earth? (Space Survival Unit) as they finalize the atomic model" (Teacher Edition, page 234)

Although there are numerous places where there is information that shows prior learning, this information is not presented in an easily accessible form for teacher reference.

Suggestions for Improvement

- Consider including the lesson level PEs from the previous lesson into the beginning of the teacher guidance portion of the subsequent lesson's "Where We Are/Are Not Going" sections. This would allow teachers to more clearly evaluate the ability of a class to move from lesson to lesson and identify any need for additional student supports.
- Consider providing teachers with a graphic organizer, table, or other organized visual showing previous learning at the element level.

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. All material presented in the unit is accurate, and teacher notes are provided to support facilitating experiences that build grade-appropriate, three-dimensional learning opportunities for students.

All scientific information in the materials is accurate. Specific teacher guidance is provided to clarify aspects of what students are learning and what may be missing, as well as to provide important information regarding scientific accuracy. Related evidence includes:

- Lesson 1: "Since this lesson elevates and captures students' questions, this is generally not the time to find answers. Certainly supporting students so they can make sense of the maps and other data is encouraged, but refrain from providing information that would answer students' questions—those questions should drive students' future investigations. So, for instance, it is expected that your initial consensus model will contain several areas of uncertainty. It will be very basic and incomplete, with the point being that the class will revise, add to, and expand that model as they figure out more about how lightning works" (Teacher Edition, page 32).
- Lesson 4: "Students may or may not come into this unit or lesson with a preexisting concept of charge or of opposite charges attracting. Until students have engaged with the readings in Lessons 4 and 5, probe those ideas. Push students to be more specific about what they mean by 'charge.' Emphasize that we need direct or trusted indirect evidence from investigations or observations (empirical evidence) in order to be sure how charge applies to lightning and other phenomena" (Teacher Edition, page 96).
- Lesson 5: "Students will learn about the movement of electrons between atoms in this lesson, but they will not investigate electron shells or make arguments about stability in this unit. A deeper understanding of electrons' location in and movement about atoms will be developed in OpenSciEd Unit C.3 How could we find and use the resources we need to live beyond Earth? (Space Survival Unit). This unit will begin to introduce the idea that electrons do not orbit atoms in the same way that planets orbit the Sun, although full understanding of quantum mechanisms is beyond the high school grade band. Students will similarly not use the periodic table to identify atomic mass or atomic number until this next unit" (Teacher Edition, page 114).
- Lesson 10: "This lesson also marks a shift in terminology from what students might be familiar with. The term 'potential energy' tends to make students think that it is energy that could exist

or is not real and obfuscates the mechanism by which energy is stored. For this reason, after students have established where the potential energy is (in the electric field that is, the space between the charges), we encourage use of the term 'energy in the field'" (Teacher Edition, page 203).

- Lesson 11: References are supplied on the reading selections, indicating the original source for the text. "Barth, P., Stüeken, E.E., Helling, C. et al. Isotopic constraints on lightning as a source of fixed nitrogen in Earth's early biosphere. Nat. Geosci. 16, 478–484 (2023). https://doi.org/10.1038/s41561-023-01187-2" (Lesson 11 Reading, Power of Lightning).

Teacher notes are provided when additional science concepts not in the lesson are relevant and may help with scientific understanding. For example:

- On the "What are recommended adult-level learning resources for the science concepts in the unit" page, a series of links to text and video resources are provided to deepen teachers' knowledge about topics such as lightning safety, lightning myths, fields and energy transfer in and out of fields, etc. (Teacher Edition, page 24).
- Lesson 2: "If students mention 'static' or 'static electricity,' take a moment to discuss what they think these terms mean. The goal is not a fully fleshed-out or 'dictionary' definition, but a gauge of students' current conception(s). An example might be 'the phenomenon when you scuff your feet on the carpet and touch someone to shock them'" (Teacher Edition, page 69).
- Lesson 5: "Understanding that losing an electron makes an atom more positive can be counterintuitive for many students. It may be helpful to draw a few hypothetical combinations of protons and electrons on the board to show students visually that when an electron is lost, there are more positive charges than negative charges left in the atom. This makes the net charge of the atom positive. Students will have more chances to practice this idea during the paper clip modeling activity in the next step" (Teacher Edition, page 122).
- Lesson 10: "Students may be familiar with the term potential energy and may want to use it in these discussions. If so, ask students to clarify what they mean by potential energy. When it becomes clear that they are referring to the energy stored in the electric field, suggest using that terminology as it more clearly indicates what is happening in the system" (Teacher Edition, page 208).
- Lesson 11: "Some of your students may bring up the term 'plasma,' referring to an ionized gas…This is an accurate way to refer to the air along lightning's path. Use your discretion to decide if, or how much, you will dig into this term. Elicit ideas about what students think plasma is, and if you wish to identify it as the fourth state of matter and give neon signs as a familiar example. If your students are more curious, they could of course keep exploring the idea of plasma on their own" (Teacher Edition, page 228).

Suggestions for Improvement

None

II.E. DIFFERENTIATED INSTRUCTION

Provides guidance for teachers to support differentiated instruction by including:

i. Supportive ways to access instruction, including appropriate linguistic, visual, and kinesthetic engagement opportunities that are essential for effective science and engineering learning and particularly beneficial for multilingual learners and students with disabilities.

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 teachers are provided with resources needed to support students using several different learning modalities as well as opportunities to learn inclusive of students with difficulty reading and multilingual learners as well as those with interest in extending their learning. However, concrete guidance for students with physical impairments is not explicitly addressed and ideas for adapting learning activities for students with a physical disability do not appear to be present in the unit reviewed.

Differentiation strategies to address the needs of multilingual learners are provided in the unit. For example:

- Lesson 3: Teachers are asked to consider that "students may not use or know the terms attraction or repulsion, but look for gestures that indicate those interactions, such as students moving their hands closer together or farther apart, or pulling and pushing motions. Make sure the class agrees that the terms for the interactions they see are attraction and repulsion, and encourage students to write the terms in their notebooks" (Teacher Edition, pages 81–82).
- Lesson 3: Teachers are told that "students may not use or know the term 'static electricity.' However, many students will have experienced it and may refer to the phenomenon using other terms. Make sure the class agrees upon a term for the interactions they see as encapsulating all of the interactions they have observed, such as 'when objects become charged and interact with each other,' and encourage students to write those terms in their notebooks" (Teacher Edition, page 88).
- Lesson 4: "The reading has been broken down into three chunks of text. This not only will help students to make sense of the text, it is also a strategy that can be used to support emergent multilingual learners. Also consider having students break down compound words like

electrostatic force. Ask students to reason about the first part of the word by asking, What does electro sound like? What other words have you heard that sound like that? Students will probably say 'electricity.' Encourage students to consider and suggest cognate words in other languages as well, such as electricidad (Spanish), électricité (French), elektrichestvo (Russian transliteration), or Elektrizität (German). Then summarize the idea of putting both words together 'electricity' and 'static' to make a single compound word that indicates that this force's association with both phenomena" (Teacher Edition, page 106).

- Lesson 5: "You may wish to provide students with sentence starters to make claims instead of asking for evidence. Scaffolds like sentence starters can model and facilitate particular oral or written language production skills, such as formulating questions, hypotheses, explanations, or arguments based on evidence. You may want to provide a skeleton statement for students to complete (i.e., If static interactions and lightning are (not) related), then we will see if they need additional support expressing their ideas. This also provides an opportunity to remind students about the difference between correlation and causation, discussed in Lesson 2. Remind students that seeing something similar does not mean they have the same cause. This can motivate the need to learn more information about the mechanism of electric charge to explain what we observe" (Teacher Edition, page 116).
- Lesson 6: "How Lightning Starts has a reading protocol built in to help students make sense of the science. Emergent multilingual learners may benefit from using this protocol as the text has been chunked into smaller sections with places to record the main ideas of each section of the text" (Teacher Edition, page 141).
- Lesson 8: "Use the word polar in its geographic context (the 'ends' of the Earth) to help students think about the meaning of polarization. Polar has cognates in many Indo-European and influenced languages, and is an exact cognate, polar, in Spanish. Induce also has cognates in Spanish and French, and students may connect with medical examples like 'noise-induced hearing loss' and 'induced' labor before childbirth" (Teacher Edition, page 182).
- Lesson 9: "This assessment includes sections of reading of a few sentences at a time, with the alternate N95 Mid-unit Assessment featuring longer chunks of reading. As desired, support emergent multilinguals and other students by printing off the assessment in sections. Read through a section as a class and clarify text meanings and question intents before allowing students to proceed" (Teacher Edition, page 195).
- Lesson 11: "Leverage students' prior familiarity with insulation and conduction in heat contexts from Cup Design Unit and Polar Ice Unit. In addition, consider leveraging cognates and loan words. Insulator and conductor terms have cognates or near cognates in many Romance languages and serve as the basis for loan words in many other languages. Also work with students to distinguish between conductor as defined here and as the leader of a band or orchestra, as well as conduct as referring to behavior in formal contexts" (Teacher Edition, page 223).
- Lesson 12: "It may help emergent multilinguals, as well as other students, to physically model conductivity and resistivity. Have one student pass through two lined-up rows of chairs (high conductivity), while another student should (safely) try to pass through a randomly arranged

line of chairs (high resistivity). Encourage students to sketch these representations next to these terms in their personal glossaries" (Teacher Edition, page 243).
- Lesson 13: "Highlight to students that scientists, in English as well as other languages, like to use combinations of words that are used in various contexts in order to make new terms. In this example, we developed the idea of ions in Lesson 11 and bonds in Lesson 12. Therefore, an ionic bond is a bond between ions. Meanwhile, an ionic compound is a compound (substance made of different types of atoms) that is made of ions (atoms that have lost or gained one or more electrons)" (Teacher Edition, page 263).

Differentiation strategies are provided to address learners who read well below grade level. For example:
- Lesson 1: Teacher discretion is encouraged when potentially deciding that "Power of Lightning may be converted to a jigsaw by placing students in groups of four and allowing students to focus on only one section. If you do this, provide time for students to meet with others who read the same section before returning to their home groups, to ensure each home group has a confident expert in each section" (Teacher Edition, page 230).
- Lesson 5: Students use a close reading protocol that begins with students previewing ideas in order to set a purpose for reading. After that discussion, the teacher is told "Say, 'Great! Now that we have some idea about what things we want to look for as we read let's take a moment to use a reading strategy to help us make sense of the reading.' Display slide H and distribute Structure of Matter. Pair students up to complete the reading. Tell students that one person should read the first two sections and the other person should read the last two sections. Give students about 10 minutes to complete this activity and discuss the central ideas with their partners" (Teacher Edition, page 118).
- Lesson 6: Students prepare to read a scientific text by answering a guiding question "why are we reading this article?" in their science notebook. Following this, they "Gather information about a reading. Display slide E and hand out How Lightning Starts. Have students gather information about what's happening in the sky before a lightning strike while they read. They will use this at the end of the lesson to compare the lightning system to our in-class static systems. Give students about 10 minutes to read and annotate How Lightning Starts. As students read, rotate around the room and assist as needed" (Teacher Edition, page 141).
- Lesson 12: "Connect, Extend, Question is provided as a reading scaffold that students can use instead of the Coherent Reading Protocol featured in Lesson 4 and Lesson 5. The provision of this support to all students supports engagement by assisting all students to deepen their understanding of technical text from wherever they are" (Teacher Edition, page 242).
- Lesson 13: "If you wish to provide students with additional support with this short reading, consider reading as a class. Support students in public reading by allowing them to read with a small group in chorus or by asking for help with word pronunciations before beginning" (Teacher Edition, page 257).

Differentiation strategies are provided to address learners who have already met the targeted PEs or who have high interest in the subject matter. However, supports are not provided to extend students' CCC-related learning. For example:

- Lesson 1: "The goal with the maps in this extension activity is to acknowledge that wildfires can be caused by lightning (among other causes) and to elicit students' thinking and connections to the impacts of lightning. In this unit, students will not investigate how lightning causes fires, why some areas are more susceptible to wildfires, or the damage done by fires. Suggest that students look for similarities and differences between these three maps and the other maps and data students examined on previous slides. Give students a few minutes to work with their groups" (Teacher Edition, page 42).
- Lesson 5: "Consider encouraging students to try the sticky tape investigation using tape they have at home. Provide random tape to students who request it. Warn students it may not work with any kind of tape and have them reflect on why that might be the case" (Teacher Edition, page 120).
- Lesson 8: "Provide balloons and/or paperclip models for students to take home so that they can demonstrate the phenomenon from this lesson, as well as Coulomb's law, to their families. Have them report back at the start of Lesson 9" (Teacher Edition, page 185).
- Lesson 12: "If students have been particularly interested in lightning safety as it relates to vehicles, or if you have noticed that students have the misconception that tires insulate the car and that is why they are safe during lightning, this can be a time to address it as an extension opportunity. Relate the metal in a car to the copper atoms in Metals/Nonmetals Comparison and tell students that rubber, like cellulose, is made mostly of carbon and hydrogen atoms. Then have them explain which part of the vehicle will protect them from lightning and how it can do so. Alternatively, have students share their explanations with their families as home learning, and return to class with additional ideas about what people should do to stay safe in storms" (Teacher Edition, page 249).
- Lesson 13: "Different types of salts, beyond table salt, are introduced in this home learning reading. It prompts students to record new questions they have at the end of it. If students raise questions about how well other salts conduct electricity compared to table salt, you can have them design and carry out an investigation using equipment in this lesson over the next few days if they are interested" (Teacher Edition, page 269).
- Lesson 13: "Students may have added questions about the water dropper to the DQB throughout the unit. Students now have the ability to answer these questions. You may wish to have students model the water dropper given what they have figured out to this point, using the template included in Model Interactions from Lesson 3. Additionally, have them model how the water dropper might behave differently if salt water is used instead of normal tap water. Students' models will show a variety of pieces that will be important in Lesson 14, including charge movement in metals, water, and air, as well as the attraction between opposite charges that results in an energy transfer between pennies. A sample model is below" (Teacher Edition, page 277).
- Lesson 14: "If a large number of questions remain on the Driving Question Board that will not be answered in other units (for example, details about different types of lightning), students may

research these questions as an extension to the unit" (Teacher Edition, page 292).

Supports are provided for students who are struggling with the material. For example:

- Lesson 1: A margin callout offers an optional slide "if students would benefit from more time to build understanding then continue with the optional activity on slide Q" (Teacher Edition, page 43), which provides an opportunity for students to review aspects of modeling such as components, relationships, interactions, and mechanisms with the action of kicking a ball.
- Lesson 1: "If students are struggling to generate questions connected to their previous observations, direct them back to their Notice and Wonder charts, related phenomena list, and initial models. If students are struggling to seek information, point them back to specific places in their initial models and ask, What would you need to know more about to figure this out?" (Teacher Edition, page 52).
- Lesson 2: "If students struggle to make sense of the differences between causation and correlation, you could provide some examples. See https://www.statology.org/correlation-does-not-imply-causation-examples/ for additional support" (Teacher Edition, page 66).
- Lesson 3: "Building prerequisite understandings: Students should be familiar with distance forces from middle school (formally) and everyday life (informally). If students struggle where to begin their revised models, elicit ideas about where else we see objects push or pull one another when they are not touching. Students may mention gravity and magnets. Encourage students to use one of these ideas as a basis for their models. Students will leverage this thinking more in the next lesson in the lead-up to formalizing electrostatic forces" (Teacher Edition, page 83).
- Lesson 5: "You may wish to provide students with sentence starters to make claims instead of asking for evidence. Scaffolds like sentence starters can model and facilitate particular oral or written language production skills, such as formulating questions, hypotheses, explanations, or arguments based on evidence. You may want to provide a skeleton statement for students to complete (i.e., If static interactions and lightning are (not) related, then we will see __________________) if they need additional support expressing their ideas" (Teacher Edition, page 116).
- Lesson 5: In an Additional Guidance note, a video resource is provided that can be helpful for students that are absent or may be struggling "to make sense of what is happening to each of the index card atoms as paper clip electrons are moving between them" (Teacher Edition, page 124). In an Assessment Opportunity note, specific strategies are provided to use with students who are having trouble identifying the net charge (Teacher Edition, page 125).
- Lesson 7: An alternate activity is provided for students that would benefit from additional practice with calculations and reasoning using Coulomb's Law (Teacher Edition, page 171).
- Lesson 8: "To help all students summarize or explain the complex ideas they figured out last class, sentence starters may be useful. Sentence starters can include: When we did the Electrostatic Force Investigation, we found that the data showed that… We saw (description of the data or patterns) in our investigation" (Teacher Edition, page 177).
- Lesson 8: "If students are struggling with where or how to move the 'electrons' on their paper clip model, prompt them by asking if they think the paper became charged and that it lost or

gained electrons. Students may also move the paper clips toward the balloon instead of away from the balloon. If they do this, ask what assumptions they are making about the charge on the balloon. Even though students should see that the balloon is negatively charged in the simulation, as long as they can correctly explain why they moved the paper clips the way they did in terms of charge on the balloon, it does not matter whether they assume the balloon is positive or negative" (Teacher Edition, page 182).

- Lesson 9: "Reflect on modeling. As students finish revising their models, display slide F and distribute Modeling Reflection. Explain to students the importance of acknowledging and celebrating both our own growth, as well as that of the class. Give them a few minutes to complete the reflection. You do not have to collect these reflections, but you may wish to encourage students to share them with you if they recognize that they are struggling with modeling or with particular science ideas. Remind students that tomorrow's work will include a mid-unit transfer task" (Teacher Edition, page 194).
- Lesson 10: "If students struggle to identify the source of energy transfers in and out of the field, present https:// openscied-static.s3.amazonaws.com/HTML+Files/Energy+in+a+Two+Charge+System.html and ask students what changes occur when particles move apart" (Teacher Edition, page 208).
- Lesson 13: Students examine claims about lightning safety related to the geese phenomenon. "If students are struggling to interpret the claim, start by helping them break down the claim into parts and make sense of the scenarios described by the claim. If students are struggling to evaluate the claim after making sense of what it means, push students to refer to their conclusions from the investigation and their key takeaways from the Scientists' Circle by verbalizing the patterns they noticed in the evidence they collected in Salt Investigation Plan" (Teacher Edition, page 276).

Suggestions for Improvement

Consider including provisions for students with disabilities, particularly those with physical disabilities. Simply working in a group may not provide equitable access to the learning experiences desired.

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials support teachers in facilitating coherent student learning experiences over time. Students are engaged in learning throughout each lesson. Support is provided to connect students' experiences from lesson to lesson and three-dimensional focus is placed on student sense-making opportunities.

Teachers are provided guidance throughout the unit to highlight intended student learning experiences and support for building three-dimensional learning. Related evidence includes:

- Each lesson within the Teacher Edition includes a "previous lesson" section as a succinct descriptor of the learning that should have already taken place. For example:
    - Lesson 2: "We watched videos of lightning strikes and discussed stories about lightning. We looked for patterns in data of lightning occurrences and fatalities caused by lightning. We developed initial models and an initial consensus model for what causes lightning and how certain factors influence it. We listed related phenomena, then generated questions and shared them to organize our Driving Question Board" (Teacher Edition, page 57).
    - Lesson 3: "We identified the parts of our initial consensus model. We collectively analyzed data that showed a relationship between rain and lightning. We considered the merits and limitations of both our initial consensus model and a physical model of lightning. We brainstormed additional objects that we could use to figure out more about what is happening in the water dropper system" (Teacher Edition, page 73).
    - Lesson 5: "We planned investigations with several different objects to generate static. We observed attractions and repulsions between several objects and looked for patterns in these interactions. We noticed that these interactions occurred after objects rubbed together and that attractions or repulsions were stronger at shorter distances" (Teacher Edition, page 109).
    - Lesson 7: "We decided to investigate what causes static interactions to occur before lightning. We read an article that could help us answer our question and gathered

information about what is happening in the sky before a lightning strike. Then, we used this information to compare the lightning system to our in-class static systems" (Teacher Edition, page 147).

- Each lesson within the Teacher Edition includes sections titled "Where We Are Going" and "Where We are NOT Going," which are used to provide information about intended learning outcomes and its fit with prior and future learning. For example:
    - Lesson 3: "The idea of attractive/repulsive forces and forces at a distance builds on students' work with distance forces in middle school in OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit). Students may not distinguish these forces as different from magnetic ones. Students may also make reference to static or static electricity, though they may not equate either with electricity produced by a battery or in the wires of devices we plug into the wall. Both of these misconceptions are okay for now, as they will be addressed in later lessons" (Teachers Edition, page 77).
    - Lesson 4: "Students have had a number of opportunities to model phenomena in this unit—lightning on paper in Lesson 1, lightning with a water dropper in Lessons 2 and 3, and most recently static phenomena in Lesson 3. This lesson continues the work from Lesson 3 in which students began investigating forces of attraction and repulsion at a distance in the water dropper system. They will continue using many of the same materials to look for patterns in attractive and repulsive forces between a variety of materials and objects. In this lesson, they further experience modeling in three ways: first, by designing a test of their model's reliability (SEP: 2.2), and second by revising their models from Lesson 3 based on the new evidence they identified in the tests of their models (SEP: 2.3). Students will also receive feedback on their models from both peers and teachers. The work on Day 1 builds on students' prior experiences with investigations in OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit), although in this lesson the investigation developed is firmly centered in testing and revising students' models" (Teacher Edition, page 96).
    - Lesson 11: "Since we use our paper clip models to make sense of the ionization of air in the lightning system, our definition of 'ion' at this point will simply be atoms that have a charge because they lost electrons. Students develop an understanding of the process of ionization and work to define it as: Ionization: The process in which atoms that were neutral become charged by losing an electron. We will not build an understanding of ionized molecules or negative ions. We do not introduce the terms cation or anion. Also, note that lightning-specific terminology, such as 'stepped leaders,' 'positive streamers,' or 'return stroke' may be helpful to your discussion, but are not critical to the sensemaking of this lesson. Use the language your students use, and it is fine if students describe what is happening in their own words and/or with less-specific vocabulary" (Teacher Edition, page 220).

Teacher guidance is provided for linking learning across lessons to ensure that students see learning as coherent. Some support is also provided for students to see how their use of the three dimensions is useful for sense-making. Related evidence includes:

- Lesson 1: "Revisit what we figured out last class about lightning" (Teacher Edition, page 43).
- Lesson 1: Students are asked to use their observations of the lightning strikes shown in slow motion to "Generate questions for the DQB. Display slide BB. Tell students to record their questions on sticky notes for each sharing and organizing. To help them generate questions, direct students to think back to the work we have done so far" (Teacher Edition, page 52).
- Lesson 2: Students revisit initial discussions about lightning and its causes, and the teacher explains "we ended lesson 1 with a lot of questions and ideas, but not a strong sense of the next step we should take. When that happens, it can be useful to return to our working model to take stock of what we know and where we have questions" (Teachers Edition, page 61).
- Lesson 2: Students use their discussion about the merits and limitations of their water dropper system to consider "how could the physical model help us answer questions from our DQB and any new questions?" (Teacher Edition, page 70).
- Lesson 3: Students brainstorm related phenomena to what they observed with the water dropper system tests, gathering their ideas on the "Related Phenomena" they started in Lesson 1, and refer to these in the next lesson (Teacher Edition, page 88).
- Lesson 4: At the end of the lesson, students individually reflect on the following prompts and then a few students share out their responses. "What questions do we have about the relationship between matter and forces (like charged matter and forces from electric fields)?" and "How do we think answering these questions might help us figure out what causes lightning?" (Teacher Edition, page 108).
- Lesson 6: As students revisit DQB progress and continue exploring the phenomenon re-solicit student contributions to the DQB by asking and listening for general questions such as "what leads up to a lightning strike?" or "what happens in the sky to cause a lightning strike?" (Teachers Edition, page 139). These questions serve as the next step in the process of coming to understand and explore the phenomenon.
- Lesson 9: "Revisit the Driving Question Board. As students wrap up their reflections, display slide G and direct them back to Our DQB Questions that they have in their notebooks from Lesson 5. Have students take a few minutes to continue analyzing the DQB questions" that have and have not yet been answered (Teacher Edition, page 194).
- Lesson 11: Students rewatch the videos of lightning strikes in slow motion from Lesson 1 and are asked "what did you notice that could help us figure out why or how the charges move between the cloud and ground?" and are eventually asked to reflect on the role that air plays in these scenarios (Teacher Edition, page 222).
- Lesson 11: "The small-scale mechanistic understandings of energy transfer that students share here (CCC) will likely help answer some questions about lightning flashes and thunder claps. This thinking requires students to use multiple lenses that show that they understand energy as manifesting itself through particle motion and energy in fields" (Teacher Edition, pages 230–231).

- Lesson 12: "Last class we figured out a lot about how lightning moves through air and what changes are happening to the atoms and molecules in the air. But what questions do we still need to figure out?" (Teacher Edition, page 239).
- Lesson 12: Students consider the structure of metals and non-metals and connect that to the conductivity of the material. "The models provide a view of the structural differences that exist between metals and nonmetals. This particle-level examination allows students to make connections between the structure of different materials and their distinct observable properties, such as electrical conductivity" (Teacher Edition, page 244)

Suggestions for Improvement

None

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. There are several locations within the unit that describe scaffolding that is used to support student development of the SEPs. However, the descriptions are rarely provided at the element level in which they illustrate the use of scaffolds and then the gradual release of those scaffolds for individual SEP elements as they are used over the course of the unit.

Information about scaffolded differentiation in the three dimensions over time is included in the Unit Overview, although information about the release of scaffolding over the course of the unit is not described at the element level.

- Unit Overview: **Developing and Using Models:** The materials state that "Because of lightning's complexity as a phenomenon and reliance on microscopic explanations, developing and using models is intentionally developed across the unit, beginning in Lesson 1 as students are supported in developing initial models using matter and energy lenses that are familiar from the Polar Ice Unit. Students have the opportunity to move between models in Lesson 2, use a model to generate data in Lesson 3, and design tests of and revise their own models (based on new evidence and peer feedback) in Lesson 4. This work builds an initial understanding of attractive and repulsive forces at a distance. In Lesson 5 they are introduced to the paper clip model to support their thinking about atomic structure. Through Lessons 8, 9, and 10, they continue to work with multiple types of models and revise their own models with increasing levels of independence using reflection and feedback. In Lessons 12 and 13 they evaluate the merits and limitations of particularly complex atomic-level models, and in Lesson 14 develop, receive feedback on, and revise individual models based on the unit's evidence and peer feedback" (Teacher Edition, page 15).

- Unit Overview: **Obtaining, Evaluating, and Communicating Information:** "Obtaining, evaluating, and communicating information is also intentionally developed across this unit. After an early focus on modeling, students compare and integrate information from different formats in Lesson 5 to figure out subatomic structure and critically read adapted scientific literature in Lesson 6. These opportunities are scaffolded with reading supports. The Lesson 6 support is particularly targeted toward helping students think about how to read scientific literature. In Lesson 11, students gather and evaluate information about interactions that result in lightning being able to pass through air. They also communicate their findings to peers. In Lesson 12, students have a less scaffolded opportunity to evaluate multiple sources of information as different students engage with different sets in different ways. They also have an initial opportunity to evaluate multiple claims about lightning's effects in Lesson 13. In Lesson 14, they communicate to their peers about lightning safety and are assessed on this practice in the end-unit transfer task" (Teacher Edition, page 15).

Students use some of the practice elements iteratively in order to develop and use them to explain more complex relationships with more complex concepts. However, the gradual releasing of specific scaffolds over time is not always clearly evident in the descriptions of student activities and supporting documents. Some representative examples:

- *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.* This element is used five times in the unit. Over the course of the unit, students gradually develop more complexity in developing and using models that show relationships between more complex systems or between more complex components of a system. For example:
    - Lesson 1: The materials provide an optional activity to reinforce an understanding of the necessary parts of a model. "Use a concrete example to think about modeling. Display slide Q. Tell students, Models should always be in service of answering a question or explaining a phenomenon. As an example of modeling, ask student volunteers to work with you to construct a model to explain: How do you move a soccer ball with your foot? Invite students to call out ideas to help you draw and label this model on a whiteboard as you identify and discuss its elements together as a class. Sample student responses are shown in the table below" (Teacher Edition, page 44).
    - Lesson 1: "Individually develop initial models. Direct students to work on their own to use the components they listed to develop their initial model. Guide them to use words and/or drawings and point out the 'zoom in' space. Remind students that we thought a lot about how to explain phenomena at the particle level in the last unit, so we want to continue using that scale of thinking about the different parts of a system to make sense of this phenomenon, too. Also remind students to complete the explanation part of the

handout. They should refer to the 'Patterns We Notice About Lightning' poster from day 1 and choose one of those ideas to explain how that factor impacts differences in lightning" (Teacher Edition, page 45).

- Lesson 4: Students use data collected from the water dropper system investigation to "revise Lesson 3 models to account for attraction and repulsion in the system. Display slide M. Ask student to do the following: 1. Revise their models based on peer and teacher feedback and empirical evidence from the investigations. 2. Explain how they used evidence, including empirical evidence from the investigations, to revise their model" (Teacher Edition, page 103).
- Lesson 9: Students develop a Gotta-Have-It Checklist that lists the components and relationships that need to be included in a model that answers the question "What causes lightning to strike at a particular place and time?" (Teacher Edition, pages 191–192). They use this checklist to develop a more complex model by revising their initial models of a lightning system with the ideas they have gained during the lessons before. Their models illustrate more relationships between components of the lightning system and include the subatomic structures of these objects (Teacher Edition, pages 193–194). Students also integrate information from prior lessons to draw models based on evidence as they complete the student assessment to illustrate relationships between static interactions (Teacher Edition, Static Interactions Assessment, pages 195–196).
- Lesson 10: "Revise the M-E-F poster. Display slide L and the M-E-F poster. Say, We have figured out a lot of important ideas in this class! Then ask about the prompt on slide L. Give students a minute to turn and talk if they struggle to respond. Listen for the following ideas: Energy is stored in the field. The field comes from charges, or charged matter. The field that stores energy is the field that causes forces. We know there is energy in the system when the particles are moving or move after being released. Energy transfers between the field and the particles" (Teacher Edition, page 209).
- Lesson 14: Students integrate information from Lessons 11–13 to develop a model that illustrates and predicts the relationships between components that explains why certain materials and places are safer than others. Peers provide feedback on student models, and students are provided an opportunity to revise their models using the feedback they receive (Teacher Edition, pages 286–288). Also, in an assessment task, students transfer their knowledge and skills about models to develop models that address a scenario that is not directly related to the lightning models they have developed during the unit. Their models seek to explain why components of airplanes and conductive gels are good or poor conductors of electricity (Teacher Edition, End of Unit Assessment, page 291).

- *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 2: Students review their initial models and answer the question "What merits (strengths) and limitations (weaknesses) does our model have that affect what it can explain?" (Lesson 2 Slides, Slide K). Later in the lesson, students determine merits and limitations of a physical model.

- Lesson 8: Students use a simulation of static attraction and respond to these questions as a class. "We have used different models in this unit. ● What merits (strengths) does the simulation have that the other models do not? ● What are some limitations of this simulation? ● How would zooming in with a paper clip model help us better understand what is actually happening?" (Lesson 8 Slides, Slide G). Students use their understanding of the different models to explain lightning polarization. "Use words and images to explain, What is happening at the atomic and subatomic level in a lightning strike? Make sure that you explain what is happening at the atomic and subatomic level in terms of electrons, charge, partial charge, and polarization. Explain how you used the simulation and the paper clip model to arrive at this explanation" (Lesson 8 Handout, Explaining Lightning Polarization).
- Lesson 10: Students revise their models, using information from their own models, the class generated M-E-F model, and the checklist of important components.
- Students do not use this SEP element on any of the assessments, and they do not have an opportunity to complete a task independently using this element. None of the questions on summative assessments ask students to evaluate merits and limitations of a model.

- *Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question ~~or solve a problem~~.* (Strikethrough in instructional materials.) This element is used twice in the unit, with more support provided the first time students use it.
  - Lesson 5: Students are provided with reading support as they practice comparing and integrating the information from the static investigations, the sticky tape investigation, and the Day 1 reading about atomic structure with the simulation on Day 2. They develop their explanation of what happens to subatomic particles during static interactions mostly as a whole-class activity (Teacher Edition, pages 123–127). They observe a video of some people talking about what happened to them when they were near lightning and identify which of these phenomena can be explained orally with the use of their models (Teacher Edition, pages 128–130).
  - Lesson 12: Students receive somewhat less support in using this element, although they do work with partners. They obtain information by examining data and models as well as engaging in a reading at different stations (Teacher Edition, pages 240–242). They examine more models of metals and non-metals, compare models of lightning rods, and integrate information from this lesson and previous lessons in order to explain why some structures are safer than others during lightning storms (Teacher Edition, pages 242–249).
- Several other SEP elements are used in the unit, but for most of those, there are only one or two opportunities for students to engage in the element. Therefore, there is no opportunity for students to gain proficiency as scaffolds are reduced.

Suggestions for Improvement

- Consider providing scaffolding information about particular parts of individual elements that are released and differentiated over time.
- To make the release of specific scaffolds for each element clearer for teachers, consider providing a document that describes differentiation of scaffolds over time through the lessons for each of the key SEP elements. As just one possible example, a key SEP element could be listed, with the lessons including that SEP element listed under the element. Beside each listed lesson, scaffolding supports that are used in the lessons nearer the beginning of the unit could be described with each lesson, with descriptions of how this scaffolding is released included in the lessons as they progress through the unit.
- Consider adding additional experiences for the SEP elements of **Obtaining, Evaluating, and Communicating Information** so that students can progress from more scaffolded tasks to tasks where they work independently.
- Consider including provisions for students with disabilities, particularly those with physical disabilities, to gain independence in using the targeted SEP elements. Simply working in a group may not provide equitable access to those learning experiences desired.

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 DCIs and CCCs to make sense of phenomena or design solutions. Students are routinely offered opportunities to engage with the three dimensions to serve as necessary tools for sense-making related to the central phenomenon. Grade-appropriate elements of the three dimensions are often developed and assessed in the unit. Students produce a variety of artifacts showing their understanding. In summative tasks, students use elements of the three dimensions to respond to questions. However, in some instances, student-produced artifacts do not directly incorporate the use of the claimed CCC element.

Materials routinely elicit evidence that students integrate the three dimensions in service of making sense of phenomena and solving problems. Related evidence includes:

- Lesson 3: “What to look/listen for in the moment: Students test for attractions and/or repulsions between parts of the water dropper system and their test objects (SEP: 2.6; DCI: PS2.B.2). Students notice relationships between the strength of interactions they observe and the time since the water dropper last sparked (SEP: 2.6; DCI: PS2.B.2). Students relate their observations of interactions and sparks in the water dropper system to the lightning phenomenon (DCI: PS2.B.2; CCC: 3.2). What to do: If students’ observations indicate only direction of interaction (attraction or repulsion) and nothing about strength or relationship to the spark or other parts of the water dropper system, ask them how they think these might impact the interaction. Encourage students to use their test objects in different parts of the water dropper system and to pay attention to how the strength of observed interactions changes depending on the location of the test objects and the timing relative to the spark. Building toward 3.A.1 Use the water dropper model to generate data at a smaller scale to identify the various causes of macroscopic attractions, repulsions, or energy transfer in lightning and lightning-like systems. (SEP: 2.6; DCI: PS2.B.2; CCC: 3.2, 2.4). Phenomena and problems are used in formal assessment tasks and are used to drive student sensemaking” (Teacher Edition, page 84).
- Lesson 4: “What to look/listen for in the moment: Students articulate what materials they plan to test their model with to produce static electricity, how they plan to produce static electricity, and how they plan to detect static electricity (SEP 2.2; DCI: PS2.B.2). Students develop plans that identify patterns of interactions that would provide evidence of the reliability of their models. (SEP 2.2; CCC: 1.5). What to do: If students have difficulty articulating any pieces of their

investigation, it may help them to talk through their plan with you. As they explain what they plan to do, help them identify materials, anticipated interactions, and detectors they will use. Encourage them to return to their models and identify what is uncertain or untested, and ask them to consider the patterns that would provide evidence of reliability and the materials that could help them do that. Once students have completed their investigation plans, make sure to collect models before day 2. Use Modeling Peer Rubric to expand on the feedback students received from their peers. Building toward 4.A.1. Develop a test of a model's reliability and revise a model based on empirical evidence of patterns to explain attractions and repulsions between objects in an electric field. (SEP: 2.2, 2.3; DCI: PS2.B.2; CCC: 1.5)" (Teacher Edition, page 100).

- Lesson 11: Question 4 asks "Which explanation best illustrates the cause-and-effect relationship between lightning and molecules in the air to form nitrates?" The students select one of four choices. "The energy from lightning heats up molecules, causing them to react to form new molecules (nitrates). The energy from lightning transfers into the fields around charges in the air which [sic]. This causes attraction between ions and other particles in the air to form new molecules (nitrates). The energy from lightning causes particles to move apart and come back together. When they smash back together they react to form new molecules (nitrates). The energy from lightning causes particles to break up to form new molecules (nitrates)" (Exit Ticket, page 4). Question 8 asks "The reading talked about one impact of electrical forces on matter interactions between air and soil. To understand how electrical forces affect other materials, what types of information would you want and how might you find trustworthy information?" (Exit Ticket, page 5).
- Lesson 14: Question 1 instructs "A friend heard that airplanes can get struck by lightning and is wondering about how everyone on the airplane would be safe if this happened. Use the graphic and words to communicate how the design of the airplane works to protect the crew, passengers, and electronics. Annotate the graphic to show the location and flow of electrons in the metal covering of the airplane before and after the lightning strike. Use multiple formats (graphic, writing) to communicate the design and performance of the airplane's safety system to your friend. Explain how it protects the crew, passengers, and electronics inside during a lightning strike. Include scientific information about the relationship between the structures in the materials and how that leads to the functionality of the design (safety)" (Assessment End-of-Unit, page 1). Question 2 asks "Aluminum is a great material to protect a plane from lightning, but aluminum coverings also prevent some important communication devices from working. Electrical engineers had to figure out a way to move lightning through the airplane's shell while exposing the communication devices. Their solution is called a radome. The radomes are made of insulating materials like plastic that cover any of the communication devices found on the front nose of the airplane. Inside is space for all of the communication devices. Radar and wireless communication can pass through the plastic of the radome, but lightning cannot. How is this possible?" (Assessment End-of-Unit, pages 1–2).

Students produce a variety of artifacts. Most of these artifacts show evidence of grade level SEPs and DCIs, with some artifacts showing evidence of students using the CCC elements. Related evidence includes:

- Lesson 1: "Initial Model With a partner: Brainstorm components you want to include in a model that answers the question, What causes lightning to strike at a particular place and time? List those components here: … On your own: Using the list you made with your partner, develop your model. Be sure to include and show relationships between the components you brainstormed" (Lesson 1 Handout Initial Model). Notes to the teacher indicate that students should be using CCC elements in this model. "Guide them to use words and/or drawings and point out the 'zoom in' space. Remind students that we thought a lot about how to explain phenomena at the particle level in the last unit, so we want to continue using that scale of thinking about the different parts of a system to make sense of this phenomenon, too. Also remind students to complete the explanation part of the handout. They should refer to the 'Patterns We Notice About Lightning' poster from day 1 and choose one of those ideas to explain how that factor impacts differences in lightning" (Teacher Edition, page 45).
- Lesson 5: Students complete an Exit Ticket. "This Electronic Exit Ticket mainly assesses student's knowledge around LLPE 5.B Develop, use, and discuss the merits and limitations of multiple models to simulate the charged substructures of atoms, the movement of electrons, and other processes and structures too small to directly observe. (SEP: 2.1, 2.4; DCI: PS1.A.1; CCC: 3.2, 4.3) Additionally, it also assesses the SEP element from LLPE 5.A Integrate information from multiple sources to explain what is happening at a scale too small to directly observe and provide evidence for the existence of protons, neutrons, and electrons. (SEP: 8.2; DCI: PS1.A.1; CCC: 3.2)" (Lesson 5 Answer Key Exit Ticket). Question 3 on the Exit Ticket shows how students use all three dimensions in their response. "We have many experiences of electrostatic interaction in our everyday lives. What is one example where you experienced static electricity? Describe what you think is happening to the subatomic particles of the atoms in the objects that lead to the interactions you saw, and use the reading, simulation, and models from class to support your explanation."
- Lesson 7: Students complete "Solving for Force" and the optional "Coulomb's Law Practice." These both require students to consider the SEP and DCI elements, but do not use the high school level CCC element (CCC **3.5** *Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth*). The front matter also describes these activities as opportunities for students to engage with the notion of larger-scale and small-scale systems. In this activity as presented, students do not note differences in the significance of the lightning phenomenon at different scales. Instead, the differing scales are used to highlight the differences in terms of orders of magnitude and its relationship to the algebraic relationship they explore.
- Lesson 8: Students draw a model to explain lightning polarization. "Use words and images to explain, What is happening at the atomic and subatomic level in a lightning strike? Make sure that you explain what is happening at the atomic and subatomic level in terms of electrons, charge, partial charge, and polarization. Explain how you used the simulation and the paper clip model to arrive at this explanation" (Lesson 8 Handout Explaining Lightning Polarization). In this

task, students use SEP and DCI elements, but do not use this part of the CCC element: "*...and can provide evidence for causality in explanations of phenomena.*" The student handout prompt is worded with a slight difference from the Answer Key, where this prompt reads, "What is happening at the atomic and subatomic level to cause a lightning strike?" (Teacher Edition, page 349).

- Lesson 9: Students revise their model using a class developed checklist. In this revision, students consider elements of all three dimensions (SEP: **2.3**; DCI: **PS1.A.1**, **PS2.B.1**; CCC: **5.2**).
- Lesson 10: Students consider the CCC of **Matter and Energy** as they complete the Energy/Charge Handout. Teacher instructions state, "The energy transfer models students develop show that energy is conserved, even when it appears to come out of nowhere. Highlight that in situations where energy seems to have been created or destroyed because of a change in temperature or particle motion, it may have simply been transferred into or out of a field" (Teacher Edition, page 206). Students use a model to illustrate *relationships between components of a system* and they observe that *when two objects interact through a field change position, the energy stored in the field is changed* (Energy/Charge Model, pages 1–2).
- Lesson 11: An Exit Ticket is used to gather information about individual students' understanding. Three of the questions require thinking about **Cause and Effect** along with an SEP or a DCI. Three questions focus only on a SEP, with one question focusing on a SEP and a DCI (Lesson 11 Answer Key, Exit Ticket Key).
- Lesson 13: Students complete a written evaluation of three different models. This task requires the use of DCI and SEP elements. (Lesson 13 Handout Model Evaluation Checklist).

The summative assessments, and at least one formative assessment, present interesting scenarios that require three-dimensional thinking to make sense of a phenomenon. Related evidence includes:

- Lesson 9: The alternate N95 mid-unit assessment presents students with a phenomenon they have not encountered in the unit but that they have likely encountered in real-life experience and asks students to explain and model what is happening in terms of what they have learned about charged interactions (Teacher Edition, N95 Mid-unit Assessment Rubric, pages 351–358). The Static Interactions mid-unit assessment does not present a new scenario, but references scenarios that students have encountered in the lessons and asks them to respond to prompts that draw out different ways of explaining what is happening (Teacher Edition, Static Interactions Rubric, pages 351–358).
- Lesson 11: The Exit Ticket presents a new phenomenon about nitrates that are caused by lightning strikes and possible claimed effects this phenomenon may have on crops (Teacher Edition, Exit Ticket Key, pages 377–381).
- Lesson 14: The End-of-Unit Assessment presents new scenarios where students must apply their understanding. Students examine structures of materials such as the radome of airplanes and conductive gels used to mimic brain tissue to explain why their properties make them good or poor conductors of electricity (Teacher Edition, End-of-Unit Assessment Rubric, pages 395–403).

Suggestions for Improvement

- In addition to using notes to the teacher to remind students to use the CCC elements in completing the student produced artifacts, consider incorporating language into the prompts and questions that steer students to include the CCC in their responses. For example, consider changing the student handout Explaining Lightning Polarization prompt to match the wording in the answer key: "What is happening at the atomic and subatomic level to cause a lightning strike?" (Teacher Edition, page 349), so that it will be clear the model is expected to show evidence of causality between scales.
- For the portion of Lesson 7 that is claimed to be addressing CCC **3.1**, consider either removing this claim or intentionally highlighting the significance of the different orders or magnitude of Coulombic forces that students note between their theoretical calculations and experimental data and its relationship to the lightning phenomenon itself.

III.B. FORMATIVE

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

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

The reviewers found extensive evidence that the materials embed formative assessment processes throughout that evaluate student learning and inform instruction. Formative assessments are included in all lessons under the title "Assessment Opportunity." This includes three-dimensional descriptions of what to look and listen for in student responses as well as how to modify instruction if students struggle with the material. Students respond in a variety of ways to demonstrate their understanding.

The materials include opportunities for formative assessment of all three dimensions that are called out explicitly throughout the lessons. Related evidence includes:

- Lesson 2: "Take a poll on the conclusion. Display slide G. Say, The graph shows us that clouds that produce lightning also tend to produce more rainfall. But does that mean one is causing the other? Assign different portions of the room to each response on the slide. Then, have students move to different parts of the room based on which statement they agree with" (Teacher Edition, page 65).
- Lesson 3: "Conduct Round 2 investigations at assigned stations. Display slide I. Assign each group to station A, B, C, or D and direct groups to the materials bin at each station. Let them know that the instructions for their assigned station are already in the bin along with the new test objects. Give groups five minutes to conduct the Round 2 investigations, and remind

students to record their observations" (Teacher Edition, page 83). Teachers are instructed that "if students' observations indicate only direction of interaction (attraction or repulsion) and nothing about strength or relationship to the spark or other parts of the water dropper system, ask them how they think these might impact the interaction. Encourage students to use their test objects in different parts of the water dropper system and to pay attention to how the strength of observed interactions changes depending on the location of the test objects and the timing relative to the spark" (Teachers Edition, page 84). Student learning is reinforced during the subsequent building understandings discussion and areas of confusion are able to be addressed using the body of evidence students generated.
- Lesson 4: "Plan investigations in small groups. Display slide G. Read through the slide directions with students and then have them work with their groups for about 5 minutes to develop their final plans. If there is still a poster or anchor chart from OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit) where students defined variables and controls, encourage students to refer to that as they think about this investigation. Encourage each group to pick a condition to vary. Then decide how to vary it, such as testing forces at various distances or testing multiple detectors under the same conditions. As groups plan, circulate to answer questions, give feedback, or push them to think deeper or be more specific in their plans and how they will serve as a test of model reliability" (Teacher Edition, page 100).
- Lesson 7: "Make additional predictions. Display slide G. Orient students to the next two conditions: adding more charge to one of the objects (Condition 2), and using oppositely charged objects (Condition 3). Have students individually record their related predictions on Predicting Force Relationships and respond to the last prompt" (Teacher Edition, page 158).
- Lesson 13: "Collect models and handouts. Display slide AA. When the timer goes off, collect Candidate Models to reuse for the next class. Collect Model Evaluation Checklist as a formative assessment" (Teacher Edition, page 268).

Formative assessment opportunities are aligned to three-dimensional learning outcomes derived from grade-appropriate elements from all three dimensions. Related evidence includes:
- Lesson 2: "What to look/listen for in the moment: Whether students think there is enough evidence to say that there is a causal relationship between falling water and lightning. (DCI: PS2.B.2; CCC: 2.1). What to do: Disagreement at this point is fine. Accept all student ideas and push back only if all students are convinced that they can definitively state that falling water causes lightning or lightning causes rain. In this case, ask students to explain how that would work and remind them that we cannot be sure that one event causes another unless we have an explanation of the mechanism supported by experimental evidence. Building toward 2.A.1 Use and move between multiple types of models to determine whether there is a correlational or causal relationship between falling water and lightning. (SEP: 2.4; DCI: PS2.B.2; CCC: 2.1)" (Teacher Edition, page 65).
- Lesson 3: "What to look/listen for in the moment: Students test for attractions and/or repulsions between parts of the water dropper system and their test objects. (SEP: 2.6; DCI: PS2.B.2). Students notice relationships between the strength of interactions they observe and

the time since the water dropper last sparked. (SEP: 2.6; DCI: PS2.B.2). Students relate their observations of interactions and sparks in the water dropper system to the lightning phenomenon. (DCI: PS2.B.2; CCC: 3.2). What to do: If students' observations indicate only direction of interaction (attraction or repulsion) and nothing about strength or relationship to the spark or other parts of the water dropper system, ask them how they think these might impact the interaction. Encourage students to use their test objects in different parts of the water dropper system and to pay attention to how the strength of observed interactions changes depending on the location of the test objects and the timing relative to the spark. Building toward 3.A.1. Use the water dropper model to generate data at a smaller scale to identify the various causes of macroscopic attractions, repulsions, or energy transfer in lightning and lightning-like systems. (SEP: 2.6; DCI: PS2.B.2; CCC: 3.2, 2.4). Phenomena and problems are used in formal assessment tasks and are used to drive student sensemaking" (Teacher Edition, page 84).

- Lesson 4: "What to look/listen for in the moment: Students articulate what materials they plan to test their model with to produce static electricity, how they plan to produce static electricity, and how they plan to detect static electricity (SEP 2.2; DCI: PS2.B.2). Students develop plans that identify patterns of interactions that would provide evidence of the reliability of their models (SEP 2.2; CCC: 1.5). What to do: If students have difficulty articulating any pieces of their investigation, it may help them to talk through their plan with you. As they explain what they plan to do, help them identify materials, anticipated interactions, and detectors they will use. Encourage them to return to their models and identify what is uncertain or untested, and ask them to consider the patterns that would provide evidence of reliability and the materials that could help them do that. Once students have completed their investigation plans, make sure to collect models before day 2. Use Modeling Peer Rubric to expand on the feedback students received from their peers. Building toward 4.A.1. Develop a test of a model's reliability and revise a model based on empirical evidence of patterns to explain attractions and repulsions between objects in an electric field (SEP: 2.2, 2.3; DCI: PS2.B.2; CCC: 1.5)" (Teacher Edition, page 100).
- Lesson 7: "What to look/listen for in the moment: Students' graphs show a predicted trend (linear or nonlinear) line of decreasing y-values as x-values increase. They show a second line on the same graph with a similar trend line as the previous one, but with a shift upward in some or all of the y-values (SEP: 5.2, 6.1; CCC: 1.4). Students label the lines in terms of the relative amount of charge they represent (SEP: 5.2, 6.1; DCI: PS2.B.1). What to do: Spot check student work before moving on to the investigation. Ask students who have not labeled their graphs to revisit their work. Building toward 7.A.1 Make qualitative claims using mathematical representations of patterns in how amount of charge, distance between charges, and strength of forces are related across the class results; and compare these to patterns predicted by Coulomb's law. (SEP: 5.2, 6.1; DCI: PS2.B.1; CCC: 1.4)" (Teacher Edition, page 158). However, the formative assessment guidance does not fully support student use of the claimed CCC element.
- Lesson 13: "What to look/listen in the moment: The answer key Model Evaluation is provided to support you in checking whether students can: evaluate the merits and limitations of different models by considering how well (or not) they show the cause of dissolving (SEP: 2.1; CCC: 2.2).

evaluate the merits and limitations of different models by considering they provide a mechanistic explanation for salt dissolving in water and electrical conductivity through it (salt water) (SEP: 2.1; DCI: PS1.A.3, PS2.B.3). What to do: Some students may not have seen all of the models yet, so some students will not have additional key ideas listed (since they have not yet seen a valid model). If you notice that students who have seen Jadon's model (the accurate one) have not captured the necessary ideas, you might choose to facilitate a fishbowl-like shared discussion with two students: one with Jadon's model and one with another model. As the pair 'thinks aloud' through their checklist, support their discussion as needed and pause to have the class point out key ideas to capture on their check lists. Building toward 13.B. Evaluate different models to determine which best explains what causes salt to dissolve in water and what causes electricity to be conducted through it (salt water). (SEP: 2.1; DCI: PS1.A.3, PS2.B.3; CCC: 2.2)" (Teacher Edition, page 268).

The materials include assessment opportunities that are explicitly called out and occur multiple times within each lesson, with clear guidance provided for how teachers can modify instruction based on student responses. A variety of formative assessments are frequently built directly into instructional sequences. The following examples are from a lesson with several instructionally-embedded assessment opportunities that include teacher guidance. These examples are representative of what occurs in other lessons:

- Lesson 5: In the discussion following the reading of Atomic Structure, when students add their ideas to their Progress Tracker, the materials provide the following information for teachers: "What to look for/listen for in the moment: Students name the three main subatomic particles (protons, neutrons, and electrons) along with their charge, relative mass, and location in the atom (DCI: PS1.A.1). Students use information from the reading to explain how scientists performed experiments to understand what was happening on a subatomic scale because they could not explain macro-scale static interactions with the existing atomic models (SEP: 8.2; CCC: 1.2). What to do: In order to make sure that students have made the connection between the experiments explained in Structure of Matter and their results, prompt them to explain their reasoning as they share what properties they learned about each subatomic particle" (Teacher Edition, page 120).
- Lesson 5: As students add more information to their Progress Trackers about what they have learned about the properties of subatomic particles, the materials provide this formative information for teachers. "What to look for/listen for in the moment: Students use information from the simulation to identify that net charge is determined by the relative number of protons and electrons in an atom (SEP: 8.2; DCI: PS1.A.1). Students use the simulation to examine interactions at the atomic scale to explain the relationship between subatomic particles and charge (DCI: PS1.A.1; CCC: 3.2). Students refer to the reading, the simulation, and the investigations in prior lessons to provide evidence for their ideas (SEP: 8.2). What to do: If students are not using multiple information sources in their discussion, prompt them by asking if there are other sources of evidence that support their ideas. If students have trouble transferring the ideas from the readings, simulation, and previous investigations into a summary

table, redirect them to the model of a particle used in previous units (a sphere) and ask how to update it based on what they have learned" (Teacher Edition, page 123).

- Lesson 5: Later in the lesson, when students use the paper-clip models to show electron movement, the materials provide the following information. "What to look for/listen for in the moment: Students simulate how moving electrons change the net charge on an atom (DCI: PS1.A.1; CCC: 3.2). Students explain how the physical paper clip model represents the same charged atomic substructure as the models described in Structure of Matter and the simulation (SEP: 2.1, 2.4; DCI: PS1.A.1). What to do: If students have trouble identifying net charge, have them count the number of protons drawn on the index card and the number of paper clip 'electrons' attached to the edges of the index card. Use this physical model to reinforce why losing an electron makes the atom more positive and adding an electron makes the atom more negative. Have students practice transferring multiple paperclips between index cards in order to have more opportunities to practice identifying the net charge of the atom" (Teacher Edition, page 127).
- Lesson 5: As students evaluate how their use of the paper clip models help them visualize and understand about what is happening to the particles in the atoms that make up the sticky tape to cause static interactions, the materials provide the following information for teachers. "What to look for/listen for in the moment: Students explain that the loss or gain of electrons changes an object's net charge, leading to changes in how objects are attracted to or repelled by each other (DCI: PS1.A.1; CCC: 4.3). Students use a physical model to develop a small-scale mechanism to explain investigation results (large scale) (SEP: 2.4; CCC: 3.2). What to do: Have students use their paper clip models and/or their diagrams of the atom to explain what is happening to the sticky tape. If students are unsure what is creating the forces that they observe, have them track the changing net charge on their models of tape A and B through each step of the example" (Teacher Edition, page 127).

Suggestions for Improvement

None

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	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the included aligned rubrics and scoring guidelines help the teacher interpret student performance for all three dimensions. The unit materials clearly state assessment targets in all three dimensions. Teachers are provided with sufficient guidance to interpret student progress through the use of what to look for in formative assessments and rubrics for Exit Tickets and summative assessments. The rubrics show various levels of student thinking on some of the questions and also help teachers plan for modifying instruction. Students also have opportunities to determine their own progress toward learning targets. However, some scoring guidance and assessment targets do not match what students are asked to do in the prompt, particularly for CCCs.

All formative assessments called “Assessment Opportunity” provide learning goals as well as what teachers should look for in student responses. Related evidence includes:

- Lesson 3: “What to look/listen for in the moment: Students mention patterns in observed interactions, such as attractions or repulsions near the metal parts of the water dropper system. (SEP: 2.6; DCI: PS2.B.2). Students mention stronger interactions when objects were closer to the water dropper system. (DCI: PS2.B.2; CCC: 2.4)….Building toward 3.A.2 Use the water dropper model to generate data at a smaller scale to identify the various causes of macroscopic attractions, repulsions, or energy transfer in lightning and lightning-like systems. (SEP: 2.6; DCI: PS2.B.2; CCC: 3.2, 2.4)” (Teacher Edition, page 87).
- Lesson 4: “What to look/listen for in the moment: Students describe the relationship between charges, fields, and the electrostatic force and propose possible revisions to their models using these ideas. (SEP: 2.3; DCI: PS2.B.2)….Building toward 4.A.4 Develop a test of a model’s reliability and revise a model based on empirical evidence of patterns to explain attractions and repulsions between objects in an electric field. (SEP: 2.2, 2.3; DCI: PS2.B.2; CCC: 1.5)” (Teacher Edition, page 107).
- Lesson 7: “What to look/listen for in the moment: Students document all the steps of using an equation (Coulomb’s law) to solve for the strength of the forces in a larger-scale system. (SEP: 5.3; DCI: PS2.B.1). This might include: Writing the general equation (Coulomb's law) and the known variables, values, and units for k, q , q , and r. Substituting the known values for the correct variables in the general equation. Performing the related calculations using order of operations. Reporting a predicted force value (F) in millinewtons. Students tie the difference in scales of solutions to the mathematical relationships in Coulomb’s law. (SEP: 5.3; CCC:

3.5)….Building toward 7.B.1 Apply techniques of algebra and functions to calculate the force predicted by Coulomb's law in a larger-scale system and contextualize the significance of the phenomenon. (SEP: 5.3; DCI: PS2.B.1; CCC: 3.1, 3.5)" (Teacher Edition, page 169).

Assessment targets for grade-appropriate elements of all dimensions being assessed together are clearly stated in the scoring guidance along with information that can be used to interpret responses. Summative assessments and Exit Tickets have rubrics to guide teachers in interpreting student work. Related evidence includes:

- Lesson 5: A scoring guide for an Exit Ticket is included. However, the student prompt and the example response do not match. The prompt to students is "We have many experiences of electrostatic interaction in our everyday lives. What is one example where you experienced static electricity? Describe what you think is happening to the subatomic particles of the atoms in the objects that lead to the interactions you saw, and use the reading, simulation, and models from class to support your explanation" (Lesson 5 Answer Key). The CCC element to be assessed is "4.3 System and System Models (e.g., physical, mathematical, computer mo/dels(sic)) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales" (Lesson 5 Answer Key). Students are not required to know they are using a cognitive model in responding to this prompt.
- Lesson 9: As students take the Mid-unit Assessment task, they are assessed on the progress they have made in reaching four SEP elements, three DCI elements, and one CCC element. Each question's alignment is noted on a table included on the front page of the "N-95 Mid-unit Assessment Rubric" with an "x" denoting each element addressed by each question. For example, question 2 is shown to address SEP: **2.3**, DCI: **PS2.B.1**; CCC: **1.1**. Support for interpreting responses is included on the answer key with sections dedicated to sample responses that have "foundational understanding," "linked understanding," and "organized understanding" that are aligned to each of the three grade-appropriate dimensions (Teacher Edition, pages 359–363).
- Lesson 9: For some questions, a section on feedback provides possible actions for each level of understanding. "Linking: Support students to identify the meaning of different terms in Coulomb's law by tying them to the investigation. Ask, How did we generate charge in the investigation? How could we have increased it? How did we vary the distance? How did that affect the force? Organizing: Invite students to examine additional details in Coulomb's law as applied to these problems. Ask, What does rubbing the balloon have to do with force? or Does it matter that distance is squared and charge is not? Encourage students to think about how graphical patterns correspond to the equation that generates them by graphing a different set of values. Extending: Encourage students to consider more complex situations. Ask, How might the problem change if the balloons were partially discharged before they were brought together? or How would the problem change if we lived in a universe where distance was not squared in Coulomb's law? Or each charge was squared?" (Lesson 9 Rubric Static Interactions, page 7).
- Lesson 11: Students are assessed on the progress they have made in reaching the SEP, DCI, and CCC elements addressed in this assessment. Each question's alignment is noted on a table

included on the front page of the "Exit Ticket Key" with an "x" denoting each element addressed by each question. For example, question 1 addresses the targeted SEP and CCC while question 5 addresses the targeted DCI and CCC. Six out of the nine questions address the targeted SEP, two of the nine questions address the targeted DCI, and three of the nine questions address the targeted CCC element. Sample student responses are addressed in sections entitled "what to look for in response" and "what to do" for each of the nine questions found on the Exit Ticket (Teacher Edition, pages 377–382).

- Lesson 14: As students take the End-of-Unit Assessment, they are assessed on the progress they have made in reaching two SEP elements, one DCI elements, and one CCC element. Each question's alignment is noted on a table included on the front page of the "End-of-Unit Assessment Rubric" with an "x" denoting each element addressed by each question. For example, question 1 is shown to address SEP: **8.5**; DCI: **PS2.B**; CCC: **6.1**. Support for interpreting responses is included on the answer key with sections dedicated to sample responses that have "foundational understanding," "linked understanding," and "organized understanding" that are aligned to each of the three grade-appropriate dimensions. The section entitled "what to do" offers teachers guidance on how to adjust instruction as a result. For example, "if students incorrectly state that electrons move freely through insulators/plastic, have them look back at Metals/Nonmetals Comparison. Ask, which of the materials on the handout would most likely be similar to plastic? Which material would most likely be similar to aluminum? Help students think about design changes by examining the two photographs, or encourage students to develop images showing the design changes at both the macroscopic and atomic scales" (Teacher Edition, pages 395–403).
- Lesson 14: Rubrics are also provided that give guidance on how the assessment can be graded. "Scoring Guidance. The response elements described below would be considered exemplary at this point in the unit. These are shown in purple text or in purple diagrams below the related question. In some cases different elements of a response are identified with a + symbol. These + elements are not meant to be all inclusive, but are suggestions for different ideas your students might include. The following scoring guidance can help you identify different elements that students should (or could) include in their responses. If several of the elements marked with a + are missing from a student's response, this may indicate that the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea, or both. If all or almost all of the elements marked with a + are present in a student's response, this may indicate that the student has mastered the science ideas and is able to use them in a written explanation or explanatory model. If the elements marked with a ++ are present in a student's response, this indicates that the student is bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Students should not be penalized if ideas marked with a ++ are not present in their response" (Lesson 14 Rubric End of Unit Assessment, page 1).

Students are provided with ways of tracking their own progress. For example:

- Lesson 2: “Explain that the Progress Tracker section of their science notebooks is intended: 1. as a thinking tool to help you keep track of important discoveries that you or the class makes; and 2. to provide you a place to individually organize your thoughts and reflect on what you are figuring out without having to worry whether your ideas are correct” (Teacher Edition, page 61).
- Lesson 5: “Say, Wow! We have figured out some more properties about the subatomic particles. Let’s take a moment to add them to our progress tracker. Add a column to the right of the ‘Atomic Structure’ poster and work with students to complete the new column shown in the example. Have students add to their previous Progress Tracker entry” (Teacher Edition, page 122).
- Lesson 7: “Navigate. Display slide AA and give students time to update their Progress Trackers. If desired, you may also encourage them to add Coulomb’s law to their Personal Glossaries. A sample Progress Tracker entry is shown. Encourage students to add a note about how what they figured out relates to a phenomenon like lightning” (Teacher Edition, page 171).
- Lesson 10: “Update progress tracker. Display slide T. Give students seven minutes to update their progress tracker with any new information. A sample progress tracker row is below” (Teacher Edition, page 214).
- Assessment System Overview: “the Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena. They help students 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 students, we strongly suggest that it not be collected for a summative “grade” other than for completion. Students add to their Progress Trackers in Lessons 2, 5, 7, 10, and 11” (Teacher Edition, page 298). Though it states that progress trackers are updated in Lesson 11, no evidence was found in that lesson’s materials.

Suggestions for Improvement

Consider either adding a progress tracker opportunity into Lesson 11 or deleting Lesson 11 from the reference in the Teacher Edition, page 298.

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	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials assess student proficiency using accessible and unbiased methods, vocabulary, representations, and examples. Science vocabulary is introduced as students gain understanding of a science idea. Representations and methods show no bias and are made accessible to students. Although the tasks provide a variety of methods for student response, there are few tasks where students choose the modality to express their understanding.

Vocabulary and text volume in student assessments are grade-level appropriate. Support is provided for students to access tasks when needed. Related evidence includes:

- Lesson 2: Vocabulary support is provided when the class begins to consider causation and correlation. “Causation is when one action or event causes another. Knowing that, what do you think correlation would be? Students should respond that correlation is when two events happen together, without one causing the other” (Teacher Edition, page 64).
- Lesson 5: Students use a close reading protocol, which begins with students previewing ideas in order to set a purpose for reading. After that discussion, they “Read about atomic structure. Say, Great! Now that we have some idea about what things we want to look for as we read let’s take a moment to use a reading strategy to help us make sense of the reading. Display slide H and distribute Structure of Matter. Pair students up to complete the reading. Tell students that one person should read the first two sections and the other person should read the last two sections. Give students about 10 minutes to complete this activity and discuss the central ideas with their partners” (Teacher Edition, page 118).
- Lesson 6: Students prepare to read a scientific text by answering a guiding question “why are we reading this article?” in their science notebook. Following this, they “Gather information about a reading. Display slide E and hand out How Lightning Starts. Have students gather information about what’s happening in the sky before a lightning strike while they read. They will use this at the end of the lesson to compare the lightning system to our in-class static systems. Give students about 10 minutes to read and annotate How Lightning Starts. As students read, rotate around the room and assist as needed” (Teacher Edition, page 141).
- Lesson 8: “Update personal glossaries. Say, Scientists have a term they use for what we observed with the wall and paper scraps. We call the type of charge that occurs when electrons shift but do not actually transfer a partial charge. Scientists will show an object has a partial charge by using the Greek letter delta. Display slide K which shows students how to label this as

δ and δ. Students should draw this in their notebooks. They can draw the index card and paper clips, showing all paper clips on one side, with the paper clip side δ and the side without paper clips δ, or they can draw another representation of an atom with electrons shifted. The important thing is to label the partial charges on whatever model they draw. Have students add the term partial charge to their personal glossaries. A possible personal glossary might look like: partial charge: when electrons shift within an atom but do not transfer to another atom" (Teacher Edition, page 183).

- Lesson 9: "Administer the mid-unit assessment task. Display slide K. Distribute Static Interactions Assessment. Give students about 25 minutes to complete this assessment task…the alternate N95 Mid-unit Assessment featuring longer chunks of reading. As desired, support emergent multilinguals and other students by printing off the assessment in sections. Read through a section as a class and clarify text meanings and question intents before allowing students to proceed" (Teacher Edition, page 195).
- Lesson 14: "Navigate into the assessment. Show slide M. Say, We have figured out a lot of great chemistry ideas in this unit. Today you will have a chance to look at different problems that we can use our knowledge to figure out. Explain that students will complete this assessment in two different parts. Distribute End-of-Unit Assessment. Read through the text before each question in part one. Give students an opportunity to ask any clarifying questions before they begin. Allow students to work on part one of the assessment for about 20 minutes. If students would benefit from developing an oral explanation rather than written explanation for question 1 on part 1 of End-of-Unit Assessment, allow them time to create an oral explanation by using technology to create a voice over of their annotated graphic. Once all students have completed part one, handout part two of End-of-Unit Assessment. Explain that part 1 of the assessment was very similar to the phenomena they have studied during the unit, but that part 2 of the assessment introduces a new phenomena [sic], conducting gels. Read through the text framing part two and give students an opportunity to ask any clarifying questions before they begin. Allow students about 15 minutes to work on part two of the assessment" (Teacher Edition, page 291).

Multiple modalities for presenting and providing information are available throughout the unit, and some tasks allow for some student choice. However, for most tasks, students respond in a modality specified by the teacher. Related evidence includes:

- Lesson 1: "Introduce lightning as a new phenomenon to explore. Say, The phenomenon that we will explore in this unit is one you have probably all witnessed yourselves, but I have a video here to watch so we can all have an example to be thinking about…Play the video linked on slide A and found at [link] which shows a series of lightning strikes in real time. You may want to play the video a second time. Ask students to describe what is happening in the video—specifically, where the lightning is going from and to" (Teacher Edition, page 34).
- Lesson 5: "Develop a physical model of the parts of an atom. Display slide P and distribute one index card and three paper clips to each student. Say, We are going to use this index card and these paperclips to build a physical model of an atom. First, let's agree on what each of these objects will represent" (Teacher Edition, page 123).

- Lesson 5: In the Electronic Exit Ticket students are given the prompt "We have many experiences of electrostatic interaction in our everyday lives. What is one example where you experienced static electricity?" (Teacher Edition, page 337), and then they are asked to describe what they think is happening to the "subatomic particles in the objects to lead to the interactions you saw" (Teacher Edition, page 337). Students therefore choose an experience of their own to focus on as they answer this question.
- Lesson 8: "Explore the simulation. Say, We are not sure about what is happening at the atomic level when the balloon and paper scraps are interacting to explain why they are even interacting. I found a simulation that may help us think about what is happening at the atomic level when we put a charged object near a neutral object. Open the simulation" (Teacher Edition, page 179).
- Lesson 9: In the Static Interactions Rubric students are instructed to "Choose a set of interactions from one row of the table shown below to focus on in this part of the assessment. Circle that row to indicate which interaction you will focus on" (Teacher Edition, page 352). Although the choice is limited to two, that of a plastic spoon or a glass rod, it does provide some choice for students to select which one they can most relate to.
- Lesson 10: Students use a computational model to access information about energy transfer. "Introduce the computational model. Display slide G. Take a moment and ask students, What do you notice in the image of the computational model? Accept all responses…investigate the computational model. Display slide H and distribute Energy/Charge Model. Tell students they will have 15 minutes to use the model" (Teacher Edition, page 206).
- Lesson 14: "Navigate into the assessment. Show slide M. Say, We have figured out a lot of great chemistry ideas in this unit. Today you will have a chance to look at different problems that we can use our knowledge to figure out. Explain that students will complete this assessment in two different parts. Distribute End-of-Unit Assessment. Read through the text before each question in part one. Give students an opportunity to ask any clarifying questions before they begin. Allow students to work on part one of the assessment for about 20 minutes" (Teacher Edition, page 291).
- Lesson 14: In the Consensus Answer Key students are given a choice about a location they will model to answer the question "Why are some places safer than others when lightning strikes?" (Teacher Edition, page 405). "They can choose to center their models on staying away from bodies of water or staying inside a building with a lightning rod or indoor plumbing" (Teacher Edition, page 405). Being able to choose a scenario that students feel most comfortable with increases accessibility to performing well on the assessment.
- Evidence was not found in key assessments that students are given the opportunity to express their learning in their own chosen modality.

Summative assessments are made more accessible by the use of methods such as class reviews, Progress Trackers, and Gotta-Have-It Checklists. Related evidence includes:

- Lesson 9: Before taking the mid-unit assessment, students review their models for what causes lightning, they reflect on what they have learned from the experiences in making their model, and the class answers questions from the DQB.

- Lesson 14: Before taking the end-of-unit assessments, the class creates a checklist of essential components of the model, students then create an individual model using the checklist and get peer review on their model. Students can choose to center their models on staying away from bodies of water or staying inside a building with a lightning rod or indoor plumbing (Teacher Edition, pages 405–412). Being able to choose a scenario that students feel most comfortable with increases accessibility to performing well on the assessment.

The text in tasks is often accompanied by some visuals such as pictures, tables, graphs, and diagrams. However, in some cases, it is not clear that students have experienced the expected vocabulary used in the directions, scenarios, and expected answer samples to a degree during instruction that would enable them to answer the questions at the sample expected level response. Related examples include:

- Lesson 5: In the Electronic Exit Ticket students are provided a list of terms they are expected to use in their explanation for Question 3 (Teacher Edition, page 337).
- Lesson 5: In the Electronic Exit Ticket students are asked to "describe what you think is happening to the subatomic particles of the atoms in the objects…" Although students have discussed subatomic particles, the lesson material does not show that students have explicitly labeled them as subatomic particles.
- Lesson 7: In the Coulomb's Law task without a prompt to explain "and why" in Question 5, students will not know to add a "because" to their answer as shown in the sample answer.
- Lesson 9: In the Lightning Polarization Key the expected answer includes the term partial polarization in the expected answer. Although the terms "partial charge," "polarization," and "induced polarization" are added to student glossaries during the lesson, the term "partial polarization" is not used in the lesson and the words "partial" and "polarization" are not put together as students describe what is happening in lightning during the lesson instruction. Not having an opportunity to use a term during the instruction that is expected in the assessment answer can create a situation where the expected vocabulary has not been developed well enough for students to answer the question at an Organized Understanding level (Teacher Edition, pages 349–350).
- Lesson 14: In the End-of-Unit Assessment the assessment includes diagrams, photos, and graphs to support student comprehension of the task (Teacher Edition, pages 395–403).

Suggestions for Improvement

- Consider providing students with opportunities to choose the specific modality in which to illustrate their thinking and learning throughout the unit on formal assessment tasks in addition to the numerous different modalities used in learning activities at various points throughout the unit.
- In the Lesson 7 Coulomb's Law task, consider adding the prompt "and why?" at the end of Question 5 in order to reasonably expect that students will include a "because" with their answer.
- Consider reviewing the language, prompts, and expectations for student explanations in the assessments and comparing them to the preparatory learning that occurs before the

assessments to ensure that students have had sufficient opportunity to express their learning using the expected assessed terms and concepts during the learning opportunities before the assessment.

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. The unit includes a robust system of assessment that includes pre-, formative, summative, and self-assessments throughout that serve as opportunities to gain insight into the state of students' three-dimensional learning.

The materials contain pre-assessments. Related evidence includes:

- Assessment System Overview: This pre-assessment opportunity is described. "The initial model developed on day 2 of Lesson 1 is a good opportunity to pre-assess student understanding of models, their components, and the interactions between air, ground, clouds, rain, and some representation of lightning to try to explain electrostatic interactions" (Teacher Edition, page 294).
- Lesson 1: Following watching a series of lightning strikes on video, the teacher is directed to "ask students to describe what is happening in the video—specifically, where the lightning is going from and to" (Teacher Edition, page 34). This serves as a pre-assessment as the discussion serves as a means to reveal student prior knowledge and background with the phenomenon of lightning and lightning strikes. Only students who participate in the discussion will be "pre-assessed" in this method.
- Lesson 1: "Review the 'Patterns We Notice About Lightning' list as a whole class. Display slide N. Make any additions or edits to the 'Patterns We Notice About Lightning' poster by leading a Building Understandings Discussion about these patterns. Be explicit with students about your role as a facilitator in this particular discussion type" (Teacher Edition, page 42). Only students that participate in the discussion will be "pre-assessed" in this method.
- Lesson 1: All students are asked to "individually develop initial models. Direct students to work on their own to use the components they listed to develop their initial model. Guide them to use words and/or drawings and point out the 'zoom in' space. Remind students that we thought a lot about how to explain phenomena at the particle level in the last unit, so we want to

continue using that scale of thinking about the different parts of a system to make sense of this phenomenon, too" (Teacher Edition, page 45). In an Assessment Opportunity What to Do section, the materials suggest, "Whether students are confident in their models or not, this is an opportunity to get an early view of their thinking and to see where there may be misconceptions around what lightning is or what causes it" (Teacher Edition, page 47).

- Lesson 1: Students create individual initial models, they turn and talk with a partner about their model, they view other models in a gallery walk and then the teacher collects the models. "When you are done, collect students' models so that you can provide initial three-dimensional feedback to students" (Teacher Edition, page 51).
- Lesson 1: The materials state, "The Driving Question Board is another opportunity for pre-assessment. Reinforce students to generate open-ended questions, such as 'how' and 'why' questions and to post to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway" (Teacher Edition, Assessment System Overview, page 294).
- Lesson 1: The materials state, "The student work in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit" (Teacher Edition, page 294, Assessment System Overview).
- Evidence does not indicate a formal pre-assessment in all three dimensions. The informal assessment opportunities mentioned in the materials serve to ascertain student levels of preparation for modeling and describing the causes of a lightning strike phenomenon.

The materials contain formative assessments that measure three-dimensional learning. See related evidence under Criterion III.B.

The materials include summative assessments that measure three-dimensional learning.

- Lesson 5: The Exit Ticket Assessment Overview labels this as a summative assessment opportunity. Students complete an Exit Ticket that provides information on their use of "Developing and Using Models, Obtaining, Evaluating, and Communicating Information (SEP 8), atomic structure (DCI: PS1.A), Scale, Proportion, and Quantity (CCC 3), and Systems and System Models (CCC 4)" (Teacher Edition, page 295). Feedback guidance is provided for the teacher in order to support students in their future work with these dimensions in this unit.
- Lesson 9: "What [sic] look/listen for in the moment: Use the answer key for Static Interactions Rubric to check for student understanding. If you instead use the alternate assessment, N95 Mid-unit Assessment, use the rubric N95 Midunit Assessment Rubric. What to do: If students have trouble deciding which static interaction to choose in Part 1, you might assign them one of the choices or point them back to different Objects A, B, and C that you know they used in class. If students need to review the subatomic particles, have them label the electrons, protons, neutrons, and atomic nucleus on their paperclip models. If it would be helpful to students working through Part 2 to actually carry out the charging of the balloon and seeing how the can

is affected, provide materials and time for them to do that. Building toward 9.B Use mathematical representations of Coulomb's Law to describe and predict the electrostatic forces between objects (SEP: 5.2; DCI: PS2.B.1, PS2.B.2; CCC: 1.1)" (Teacher Edition, page 196). Two versions of the mid unit summative assessment are provided, with rubrics and scoring guidance included. However, it is not clear how a teacher is to determine which version might be appropriate for their students or whether different versions should be used by different students in the same class.

- Lesson 14: Lesson-level PEs are identified, and assessment guidance identifies two sections, 14.A and 14.B. One example says, "14.B When to check for understanding: While students are presenting their models to their trio (slide H). What to look/listen for during the opportunity: Students use their drawn model and written text as a tool to clearly communicate the scientific ideas that explain the phenomenon (SEP: 8.5) Students make connections between the molecular-level structure of the material with its function of safety during a lightning strike. (DCI: PS2.B.3; CCC: 6.1). End-of-unit Task: In this lesson you will administer the End-of-Unit Assessment task. This assessment is not building toward a lesson-level performance expectation. It is designed to assess progress toward a performance expectation from the NGSS (HS-PS2-6). See Summative Assessment Rubric for details" (Teacher Edition, page 306).

The materials contain self-assessment opportunities. Related evidence includes:

- Lesson 3: Though it is presented as an alternate activity, "the end of this lesson may be an opportunity for students to self-assess given what they have figured out so far. Such self-assessment could prepare them to give better peer feedback in Lesson 4. A standard template for self-assessment may be found in the OpenSciEd Teacher Handbook: High School Science" (Teacher Edition, page 89).
- Lesson 5: When completing the Exit Ticket "Students also have an opportunity to reflect on their own contributions to the class's inquiries" (Teacher Edition, Assessment System Overview, page 295), which relates somewhat to SEP **8** in communicating science understandings.
- Lesson 9: Students reflect as part of an ongoing self-assessment system. "Reflect on modeling. As students finish revising their models, display slide F and distribute Modeling Reflection. Explain to students the importance of acknowledging and celebrating both our own growth, as well as that of the class" (Teacher Edition, page 194).
- Lesson 10: "Complete self-assessment of lightning models from Lesson 9. Have students take out their models from Lesson 9, or pass them back if you collected them at the end of Lesson 9. Pass out the new Model Self-Assessment to students. Display slide P. Say, Recently, you revised your initial lightning model to include what we have figured out about what causes charge and what electricity is. Now look back at those models from the other day and use this self-assessment handout to help you reflect on what your model does well and what you may still need to add to your model. Give students seven minutes to work on Model Self-Assessment independently, making sure that all students at least complete the checklist in question 1 on the handout" (Teacher Edition, page 212).

The assessment purpose and rationale are coherent across the materials and are explicitly described for all three dimensions. Related evidence includes:

- A chart showing the specific SEP, DCI and CCC elements that will be assessed, and which questions involve the use of each of those elements is present for all summative assessments.
- The "Assessment System Overview" includes not only three-dimensional assessment information broken down for each unit by element and assessment, but also a description of the assessment purpose and plan for each lesson, including labels as "formative," "self-assessment," "summative," "community building," and/or "peer assessment." (Teacher Edition, pages 294–306). For example:
    - Lesson 10: Energy/Charge Model; "**Formative**. In Lesson 10, students use a computational model to build understandings of how the movement of charges in an electric field results in energy transfer in and out of the field. The key provides guidance on what students should notice, in order to support subsequent standards as students build toward completing the M-E-F model (to the extent that is done in this unit)" (Teacher Edition, page 296).
    - Lesson 14: Consensus Gotta-Have-It Checklist and Consensus Checklist Key: "**Formative and Peer Assessment.** Students develop a collaborative Gotta-Have-It checklist and individual models around the question, 'Why is it safer to be away from water and in a building with lightning protection during a storm?' Students should use evidence from throughout the unit, in particular later lesson sets. They should consider how attraction and repulsion at the atomic scale explain patterns across different scales, in particular patterns of safe practices in lightning. Students have the opportunity to communicate their understanding to peers and use feedback on the models to make revisions" (Teacher Edition, page 297).
    - Lesson 14: Lesson-level PEs are identified, and assessment guidance identifies two sections, 14.A and 14.B. One example says, "14.B When to check for understanding: While students are presenting their models to their trio (slide H). What to look/listen for during the opportunity: Students use their drawn model and written text as a tool to clearly communicate the scientific ideas that explain the phenomenon (SEP: 8.5). Students make connections between the molecular-level structure of the material with its function of safety during a lightning strike (DCI: PS2.B.3; CCC: 6.1). End-of-unit Task: In this lesson you will administer the End-of-Unit Assessment task. This assessment is not building toward a lesson-level performance expectation. It is designed to assess progress toward a performance expectation from the NGSS (HS-PS2-6). See Summative Assessment Rubric for details" (Teacher Edition, page 306).

Suggestions for Improvement

None

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 DCIs and CCCs. There are multiple opportunities for students to demonstrate their growth and learning throughout the unit as well as multiple opportunities to receive and respond to feedback from the teacher as well as fellow students throughout the unit. This feedback is often aligned to specific learning tasks but is not always geared toward progression toward each of the specific targeted elements for the unit. There is little feedback and there are few opportunities for students to show growth in proficiency in using the CCC elements that are the focus of the unit.

Students are provided with multiple opportunities to receive and respond to feedback throughout the unit on tasks using the focal SEP elements. Related evidence includes:

- Lesson 1: Students create an individual model and then revise their models with a partner. Then the class develops a consensus model on what causes lightning. The feedback occurs when students discuss their ideas and also hear the ideas of others when they are developing a class consensus model. The teacher collects the models and provides individual feedback to students.
- Lesson 4: Students use data collected from the water dropper system investigation to "revise Lesson 3 models to account for attraction and repulsion in the system. Display slide M. Ask student to do the following: 1. Revise their models based on peer and teacher feedback and empirical evidence from the investigations. 2. Explain how they used evidence, including empirical evidence from the investigations, to revise their model" (Teacher Edition, page 103).
- Lesson 5: Students develop models of atomic structure. Those models are evaluated during a class discussion. "Have students meet in a Scientists Circle and explain that we will be participating in a roundtable discussion about our paper clip models. Say, In a roundtable discussion, one group will share their models, and the rest of us will be providing feedback" (Teacher Edition, page 126).
- Lesson 7: "Highlight to students that carefully documenting their work is a skill that spans both math and science. Collect Solving for Force and provide feedback as students prepare for the mid-unit, summative task in Lesson 9. If students do not document solution steps in the first part of this handout, or report that they have answers different from those expected when comparing with their partner, then give them an opportunity to practice these skills again as home learning, this time with all values doubled" (Teacher Edition, page 169).
- Lesson 8: Students add information from their models of atomic structure and attraction and repulsion to their initial model on what causes lightning. "Instead of collecting students' models for feedback in this lesson, have them exchange models with a partner or take their model and

Gotta-Have-It checklist home in order to receive outside feedback. You may then collect students' models and provide feedback along with feedback on the mid-unit assessment" (Teacher Edition, page 193).

- Lesson 9: Students construct a Gotta-Have-It Checklist with a partner and "Switch partners to compare Gotta-Have-It Checklists. Display slide C. Direct students to work with a different partner to compare their checklists using the prompts on slide C to guide their discussion. They should acknowledge ideas they agree on and also provide evidence about including ideas they did not both list already. Remind students to revise their checklists based on this discussion with their new partner. Give students about 5 minutes to talk with these partners and revise their lists accordingly. Again, the answer key for Gotta-Have-It Checklist Key is provided as a tool for you while you circulate the room and interact with students about their work" (Teacher Edition, page 192).
- Lesson 10: Students complete a self assessment of their lightning models and then discuss their self assessment with a partner. They use their self assessment to revise their models. "Complete self-assessment of lightning models from Lesson 9. Have students take out their models from Lesson 9, or pass them back if you collected them at the end of Lesson 9. Pass out the new Model Self-Assessment to students. Display slide P. Say, Recently, you revised your initial lightning model to include what we have figured out about what causes charge and what electricity is. Now look back at those models from the other day and use this self-assessment handout to help you reflect on what your model does well and what you may still need to add to your model" (Teacher Edition, page 212).
- Lesson 14: "Individually revise models based on feedback. Display slide I. Have students return to the partner they brainstormed the Gotta-Have-It Checklist with, review their feedback, and then update their models based on that feedback" (Teacher Edition, page 288).

Students have multiple tasks in which they engage in the DCI element **PS1.A.1**. *Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.* Related evidence includes:

- Lesson 5: Students complete a reading about atomic structure. They check their understanding by completing a class poster. "Say, Great! That is a lot of information to keep track of. Let's build out a way to keep track of it. On a sheet of chart paper, develop a poster titled 'Atomic Structure' like the one below. Leave room for an additional column to the right that you will add after the next activity in the lesson. Encourage students to add the chart and any additional ideas into their Progress Tracker" (Teacher Edition, page 119).
- Lesson 5: Students use a paper clip model to add to their understanding of parts of the atom and then have a roundtable discussion and get feedback on their model by comparing their ideas to the ideas of other groups.
- Lesson 9: Students work with a partner to develop a checklist of important ideas to be included in a model, including "4. The loss or addition of electrons results in different net charges on those particles/atoms (Lesson 5). Losing electrons results in matter that is positively charged. Gaining electrons results in matter that is negatively charged" (Lesson 9 Answer Key Gotta-Have-It checklist). Students switch partners, compare checklists, and revise their own checklist.

- Lesson 9: On one of the questions on the Static Interactions Assessment, students show their understanding of atomic structure. "1a. How did the charges on atoms in Object A change when you rubbed Object A on Object B? Draw a model using the subatomic structure of an atom to explain what is responsible for the change in charge" (Lesson 9 Assessment, Static Interactions, page 2).

Although the unit presents multiple opportunities for students to use CCC elements, there are few places where students receive feedback on their thinking on specific CCC elements and then have another performance where they can show their developing proficiency. Related evidence includes:

- *Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.* (CCC **1.1**) This CCC element is used more than once during the unit.
    - Lesson 1: Students first consider the use of scale to see patterns when they view a video at different scales of time. The class discusses what they noticed and wondered, but students do not receive feedback on their thinking about scale and patterns.
    - Lesson 8: Students contrast macroscopic representations (the charged balloon and the paper pieces) with microscopic models (the paper clip model) in an attempt to gain insight into underlying causes of the observed pattern. However, students do not receive feedback on their CCC thinking.
    - Lesson 9: On the Static Interactions Assessment, students are asked a question where the response requires an understanding of this CCC element. "1c. What evidence of patterns from class support your answers to 1a and 1b? Make sure to discuss evidence from macroscopic (visible) and microscopic (invisible) scales." It is not clear that students receive feedback on this element at this time.

Suggestions for Improvement

- Consider tracking which elements of the three dimensions students are provided with iterative feedback throughout the unit. For example, a tracker could mark if and when students receive feedback and opportunities to revise their thinking on the use of DCI: **PS2.B.2** throughout the unit.
- To make it clear for teachers that there are (or could be) iterative opportunities for students to develop proficiency with feedback that leads towards more proficiency with one or more CCCs and/or DCIs, it could be helpful to provide a visual table or other concise means that illustrates these iterative opportunities in the unit. Similarly, it could be helpful for teachers to provide a visual table or other concise means that illustrates how the iterative modeling opportunities work together to provide an increased demonstration of proficiency in **Developing and Using Models** to explain phenomena. This would serve to clearly describe for teachers how the materials provide these opportunities for students to learn, receive feedback, and then have new opportunities to apply the feedback to their next models.

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

UNIT SCORING GUIDE – CATEGORY I (CRITERIA A-F)

UNIT SCORING GUIDE – CATEGORY II (CRITERIA A-G)

UNIT SCORING GUIDE – CATEGORY III (CRITERIA A-F)

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)