EQuIP RUBRIC FOR SCIENCE EVALUATION

Ecosystems: Matter and Energy

DEVELOPER: OpenSciEd

GRADE: High School **| DATE OF REVIEW:** September 2023

B.2 Ecosystems: Matter & Energy

EQuIP RUBRIC FOR SCIENCE EVALUATION

OVERALL RATING: E
TOTAL SCORE: 9

CATEGORY I: NGSS 3D Design Score	CATEGORY II: NGSS Instructional Supports Score	CATEGORY III: Monitoring NGSS Student Progress Score
3	3	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	**Extensive**	**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	**Adequate**	**D.**	Unbiased Tasks/Items	**Extensive**
E.	Multiple Science Domains	**Adequate**	**E.**	Differentiated Instruction	**Extensive**	**E.**	Coherence Assessment System	**Extensive**
F.	Math and ELA	**Extensive**	**F.**	Teacher Support for Unit Coherence	**Extensive**	**F.**	Opportunity to Learn	**Extensive**
			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. It is obvious that this unit was thoughtfully crafted, and it is strong in several areas, including:

- **Unit Coherence:** The unit has a strong emphasis on coherence and linking ideas, learning, and phenomena from different lessons. The teacher supports for unit coherence are useful (e.g., Progress Tracker, Driving Question Board (DQB), Assessment System Overview, Rubrics for Summative Tasks and Electronic Exit Tickets, Carbon Sink model, and Dead Zone task) and allow students to link their learning from lesson to lesson throughout the unit and help them make sense of the anchoring phenomenon.
- **Coherent Assessment System:** There is a very clear assessment system that provides an overview of how students are assessed throughout the unit. The purpose and rationale of each assessment is outlined as to its role within the larger unit. Each assessment builds upon the key understandings of the lessons and the overall goal of making sense of the zombie fire and global wildfires phenomenon.
- **Phenomena and Three-Dimensional Learning:** Throughout the unit, lessons are focused on students engaging with all three dimensions while making sense of phenomena. The case studies used are interesting for students and motivate sense-making and learning. All lessons are focused around making sense of phenomena and link back to the anchoring phenomenon of the zombie fires.
- Supports for teachers to attend to social emotional learning is an additional strength in the lessons. There are useful tools for students and teachers to support them as they may encounter challenging emotions while learning about global environmental issues relating to the global burning carbon sinks.

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

- **Scaffolded Differentiation Over Time**. The lessons include scaffolds for supporting student learning progressions in the three dimensions but could be clearer in noting when and how to reduce the scaffolds as students gain proficiency. Allow opportunities for students to show individual proficiency with this practice, specifically later in the unit. Some of the embedded opportunities for student choice with drawing, writing, or speaking means not all students will show individual proficiency with this practice.
- **Mathematics and English Language Arts (ELA) Connections.** Ensure that the claimed ELA connections are happening within the portion of the lesson that is claimed.
- **Scientific Accuracy with Glucose and Sucrose.** Not differentiating the two could cause misconceptions of the two molecules.

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 definitely 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

I.B. THREE DIMENSIONS

I.C. INTEGRATING THE THREE DIMENSIONS

I.D. UNIT COHERENCE

I.E. MULTIPLE SCIENCE DOMAINS

I.F. MATH AND ELA

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 and/or designing solutions to a problem because learning is anchored in the driving question, what causes fires in ecosystems to burn and how should we manage them? The unit is divided into two sets. Lesson Set 1 (Lessons 1–6) focuses on figuring out what causes zombie fires to burn under the ice and what the consequences are. Lesson Set 2 (Lessons 6–12) explores how global carbon cycling is affected by fires. A series of related sub-phenomena anchor each lesson in the unit and students regularly return to the anchor phenomenon to add layers of explanation based on their learning. However, significant teacher input is necessary in order for students to feel like their questions and experiences are driving the learning.

There are many sections in the teacher materials that help teachers identify the way that the main phenomenon is intended to drive student learning. These resources, such as the “Building towards NGSS,” “Where we are going” and “Where we are not going” sections, better equip teachers to help students make connections in their learning. Additionally, in Lesson 1, the materials instruct teachers to keep the DQB, Initial Consensus Model, Related Phenomenon, and Ideas for Investigations and Data We Need posters accessible throughout the unit to engage students with relevant tools (Teacher Edition, page 32). These tools can help teachers center student learning.

Student questions and prior experiences related to the phenomena motivate sense-making. For example:

- Lesson 1: Students are introduced to Arctic Fires using images from NASA and an article about Arctic Fires. Student observations and questions are captured on a Notice and Wonder chart (Teacher Edition, pages 34–35). Additional images are provided through an inquiry activity with five dimensions and examined in small groups and students add to their Notice and Wonder chart (Teacher Edition, page 38). A DQB is created with students’ questions and used to “generate ideas for how they could go about answering each question” (Teacher Edition, page 55). Students then prioritize the question(s) to determine the question to investigate next (Teacher Edition, page 57).

- Lesson 3: Students "Stop and Jot new questions" for the DQB (Teacher Edition, page 98). There is no guidance for the teacher to help connect these questions to the progression of student learning and sense-making.
- Lesson 6: Students revisit the DQB. The teacher is prompted with questioning to help center the students' questions in the sense-making. "How have our feelings changed or intensified since we began figuring out about fires/zombie fires? What progress do we still need to make on our question: How do matter and energy flow within the zombie fire system? What new questions do we have? How can we evaluate our progress thus far?" (Teacher Edition, page 146). There is guidance in the margins to help with ensuring student questions motivate sense-making. "Use talk strategies to draw out a wide variety of ideas from a larger pool of students. If it feels like students don't have any more ideas, don't move on right away. Instead, count to ten in your head to give students more time to consider. Have students jot down some ideas in their notebooks after their partner talks and before sharing. This can be particularly supportive for emergent multilingual students. Use questions to push students' thinking to new contexts and provide more opportunities for students to make connections to their experiences… Use talk strategies to draw out a wide variety of ideas from a larger pool of students. If it feels like students don't have any more ideas, don't move on right away. Instead, count to ten in your head to give students more time to consider. Have students jot down some ideas in their notebooks after their partner talks and before sharing. This can be particularly supportive for emergent multilingual students. Use questions to push students' thinking to new contexts and provide more opportunities for students to make connections to their experiences" (Teacher Edition, page 146).
- Lesson 7: At the end of the lesson, students add more questions to the DQB. This is after they investigate case studies of carbon sink fires (Teacher Edition, page 157). This motivates sense-making into finding out more about the impacts of these fires and begins to motivate the problem-solving aspect of the fire management plan.
- Lesson 10: There is guidance for the teacher to connect student questioning to the fire management plan. "Ask students to recall the case studies they read about in lesson 7 and the possible solutions they came up with for those scenarios. Direct them to revoice questions from the DQB or Fires Progress Tracker about ways to manage or reduce the burning of carbon sink… What questions did we have about protecting carbon sinks from burning? What ideas did you have for possible solutions to protect the carbon sinks?" (Teacher Edition, pages 214–215).
- Lesson 11: The DQB is closed out through an activity for students to consider what questions have been answered. Any unanswered questions will be kept to see if they can be answered in future units. "While not all questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this helps students see the hard work that they have done to answer many of their own questions" (Teacher Edition, page 256).

The focus of the unit is to support students in making sense of the anchor phenomenon, "fires are burning under ice and snow in the Arctic" and designing solutions to problems. Related evidence incudes:

- Lesson 1: Students are introduced to the zombie fires through an inquiry activity, articles, and photos. They also brainstorm related phenomena and develop an initial model "that illustrate [sic] and explain how energy and matter are flowing in the zombie fire system" (Teacher Edition, page 44).
- Lesson 2: The anchoring phenomena of zombie fires drives the investigation. "We know we want to investigate peat and how it burns, what other fuel sources from our related phenomenon can help us figure out more about matter and energy in fires in ecosystems?

Listen for students to bring up other fire fuels such as grass, leaves, and/or wood" (Teacher Edition, page 65). Their experiences from the investigation drive wanting to learn more about peat and why.

- Lesson 3: The students investigate decomposers and peat, which connects to the anchoring phenomena of zombie fires in the Arctic. After the investigation, there is guidance for a building understanding discussion about matter and energy in the zombie fire system. "How does this help us answer our question, Why is there so much energy and matter in peat?" (Teacher Edition, page 96).
- Lesson 4: The puzzling idea of plant matter (peat) ending up in the Arctic and being part of the zombie fires motivates students to investigate photosynthesis. "We figured out why the energy and matter have stayed as peat in the zombie fire system for a long time, but I am confused. The Arctic is so cold and snowy. How did all that plant matter get there in the first place?" (Teacher Edition, page 103). Prior experiences are used to help students understand changes in an area's temperature over time. "We have made sense of how energy and matter flow through photosynthesis, but we still have not figured out how there got to be so much plant matter in the Arctic. Can you think of times when the amount of matter and energy in plants has changed where you live or in a place you have visited? Listen for students to share ideas about changing seasons, leaves falling, or plants dying" (Teacher Edition, Page 106).
- Lesson 5: Students investigate how so much plant matter got to be stirred as peat under the permafrost, which connects to zombie fires. "Based on the data in the figures, we think there is less solar radiation in the Arctic and therefore less plant matter stored as carbon through photosynthesis. Ask students to turn and talk about the question on slide C, How is there so much energy and matter in the peat in the zombie fire system even though there is less solar radiation and photosynthesis than other places on Earth?" (Teacher Edition, page 116).
- Lesson 6: Students complete the Zombie Fore Explanation. "Use evidence from your investigations to explain: How was there enough matter and energy in the zombie fire system for a zombie fire to burn under ice? Make explicit connections between the past and future of zombie fires or related phenomena. Use the space below to jot down some notes. Then write or draw your explanation on the next page. Use your Gotta-Have-It Checklist, Fires Progress Tracker, and science notebook" (Assessment Zombie Fire Explanation).
- Lesson 7: The anchoring phenomena of zombie fires is used to consider related phenomena. "It seems like we are curious to investigate if there are other places in the world where fires are happening. What types of places would you expect to find large fires? Listen for students to mention forests, prairie, other places with peat. Ask what those areas would have in common in terms of carbon (matter) and energy. Listen for students to mention large amounts of carbon (matter) and energy in carbon sinks where there is a build up[sic] of plants or other plant-like material" (Teacher Edition, page 155). Students look at case studies of other related phenomena where carbon sinks occur.
- Lesson 8: The impacts of these carbon sinks are considered and that drives the investigation of the relationship between carbon dioxide and temperature.
- Lesson 9: Students look at data regarding carbon dioxide and global temperatures. This connects to the related phenomena and anchoring phenomena and drives the problem-solving fire management plan in later lessons.
- Lesson 10: Students use knowledge gathered from the related phenomena and anchoring phenomena to drive problem solving. "What did we figure out about global wildfires and Earth's systems in the last few lessons? What questions did we have about protecting carbon sinks from burning? What ideas did you have for possible solutions to protect the carbon sinks?" (Teacher Edition, page 215). Students consider the case studies, related phenomena of Indigenous people

using intentional burning, and their prior learning when considering the beginning stages of the fire management plan.

- Lesson 11: Students develop a fire management plan. "...prompt groups to answer the questions to use Designing Fire Solutions support them in developing their solution. They should be as specific and thorough as possible in describing and explaining their solutions and impacts where appropriate. Remind students of the conversations about power and historicity from Lesson 7 and how it led to making carbon sinks vulnerable in the case studies they read about and the criteria and constraints of the fire management strategies in Lesson 10, but also which groups were left out of decision-making in both sets of case studies. Let the class know that there aren't any 'right' or 'wrong' answers to these questions and that everyone in the room might have very different ideas about each prompt, which is absolutely okay. Encourage students to use the class consensus model and/or models from individual lessons to help them predict the impacts of their solutions" (Teacher Edition, page 247).

The navigate section of the lessons supports teachers in centering student learning and prompts students to return to figuring out the phenomenon regularly. For example:

- Lesson 2: The navigate section suggests students to reflect and share out on questions such as what they figured out about burning zombie fires in the Arctic last class and that next steps are figuring out more about permafrost and how peat can burn under ice (Teacher Edition, page 64).
- Lesson 3: The navigate section helps students link their learning from last time about peat and permafrost to new questions about peat (Teacher Edition, page 84). The sample student responses here are very open ended, considering that is towards the beginning of the unit, but it may take some maneuvering to truly have these student questions drive the learning in Lesson 3.
- Lesson 4: The navigate section prompts the teacher to problematize the presence of peat in the Arctic to help students generate questions around why there is so much plant matter in a cold and snowy location (Teacher Edition, page 103). While this centers the phenomenon and keeps student learning focused on figuring it out, it does require significant teacher guidance to keep the students learning in this direction.
- Lesson 5: In this Learning Plan for Lesson 5 section, Earth's tilt is reviewed which is a sub-phenomenon that is scaffolding students towards figuring out what led to the peat accumulating in the Arctic and connecting the last lesson to the need for an investigation (Teacher Edition, page 116).
- Lesson 6: As students pause in Lesson 6 to come to consensus around what they know about zombie fires as carbon sinks that are releasing so much carbon dioxide through burning, the three dimensions are clearly linked and in service of figuring out the phenomena — drawing models and communicating ideas with others to explain the concepts (Teacher Edition, page 134).
- Lesson 7: Teachers are prompted to draw out student responses relating to curiosity about investigating other places in the world where fires are happening, this is teeing up the learning in Lesson Set 2 that connects the phenomena in Lesson Set 1 with related sub-phenomena and global connections (Teacher Edition, page 155).
- Lesson 8: Lesson 8 begins to add a forward-thinking lens to the zombie fires phenomena. Here students are figuring out one outcome of what happens to the atmosphere and temperature when so much carbon dioxide is released (Teacher Edition, page 174).
- Lesson 9: Students are supported in linking the CO_2-temperature bottle investigation results they carried out in Lesson 8 into the analysis of global temperature trends to help figure out the

same sub-phenomena, what is the result of the burning of carbon sinks (Teacher Edition, page 191). What is important in each of these lessons is that when new phenomena are introduced, the materials include prompts for teachers and students that help link them. They are not being introduced in an unrelated, haphazard manner.

- Lesson 10: This navigate section again centers student responses and questions to figure out the phenomena, how to manage carbon sinks and in this case, learning from people who are doing that (Teacher Edition, page 214).
- Lesson 11: This section includes a strategy to have students share home learning and bring in their own experiences and ideas relating to the phenomena of fire management (Teacher Edition, page 241).
- Lesson 12: Student ideas do not drive this section. This lesson is satisfying the need for a transfer task and demonstration of understanding of the unit key concept.

Suggestions for Improvement

Consider additional opportunities to link related sub-phenomena to student prior experiences when the phenomena are introduced.

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

The reviewers found extensive evidence that the materials give students opportunities to build understanding of grade-appropriate elements of the three dimensions. Claimed Science and Engineering Practices (SEP) elements are clearly developed and used at the high school level throughout the unit, although there are limited opportunities for individual development of one of the claimed SEPs. Students use and develop grade-appropriate elements of a sufficient number of Crosscutting Concepts (CCCs) for the duration of the unit. Finally, the claimed Disciplinary Core Ideas (DCIs) are addressed by the unit.

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 grade-appropriate elements of the focal SEPs are used to make sense of the phenomenon and ultimately to design a solution to a problem. There are sufficient SEP elements and time that students are engaged in the SEPs for the length of the materials. There is a close match between the SEP elements that are claimed and evidence of SEP development and use in the materials.

However, the students do not have an authentic opportunity to develop the element of **Planning and Carrying Out Investigations** (SEP **3.2**).

Developing and Using Models

- *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system* (SEP **2.3**).
  - Lesson 1: Students develop an initial model of the zombie fire system and incrementally build the components, interactions, and mechanisms of their revised models in later lessons. Teacher prompts include asking students to identify the components of the zombie fire system, how matter might cycle in it, how energy might flow in it, how the components interact, and what mechanisms might explain what is happening (Teacher Edition, page 44). These prompts support students in focusing on the most important considerations for their initial model. Students then revise their initial individual models (Teacher Edition, page 46).
  - Lesson 3: As students write explanations for why there is so much matter and energy in the zombie fire systems, teacher prompts refer them back to their models of decomposition, peat/permafrost, and yeast (Teacher Edition, page 98).
  - Lesson 6: The class develops a Gotta-Have-It Checklist to determine what must be in student's model to explain how zombie fires burn under ice (Teacher Edition, page 136).
  - Lesson 6: Small groups develop a model of a different fire system/carbon sink. They come to consensus as a class and are prompted to identify if their own model is missing components, or if they need to add them to the model. A possible representation of the model is included for teacher support (Teacher Edition, page 140).
  - Lesson 9: Students develop a model of the flow of carbon (matter) and energy through Earth's system, revise their Gotta-Have-It Checklists and engage in a discussion to come to consensus on the model, including feedback effects (Teacher Edition, page 186). As students roll dice, they track a carbon atom's journey as it relates to matter and energy flow.
  - Lesson 12: In the Dead Zone Transfer Task, students develop a model of the carbon and oxygen cycle in the Gulf of Mexico (Teacher Edition, page 259). When students develop their models, they are aware that they are modeling what causes low dissolved oxygen and the resulting dead zone in the Gulf of Mexico, an important marine ecosystem. "Put the pieces together. What causes low dissolved oxygen and the resulting dead zone? Where does that oxygen go? Create a revised model below using pictures and/or words. Be sure to include: The steps leading to low dissolved oxygen and dead zones. The role of phytoplankton and bacteria. The inputs and outputs of photosynthesis and cellular respiration (include the flow of both matter and energy). The role of the Sun and excess Nitrogen in the water. The effect of low oxygen on shrimp and fish and wy[sic] this is the effect. Where the dissolved oxygen went and how it got there" (Dead Zone Transfer, page 10). Their model includes inputs and outputs of the system but does not use the word system.
- *Develop a complex model that allows for manipulation and testing of a proposed process or system* (SEP **2.5**).
  - Lesson 9: Students develop a model of the flow of carbon (matter) and energy through earth's system, revise their Gotta-Have-It Checklists and engage in a discussion to come to consensus on their model, including feedback effects (Teacher Edition, page 186). In the student handout, the instructions advise the students to "Enter information into the spreadsheet as follows: 1. Choose a system to begin. Roll a die and record that number in

the Dice roll column. 2. Read the card to determine what happens to matter and energy based on the roll of the dice. Use the drop-down choice under Type of carbon-based molecule (matter) to record what happens to you as matter. You could become: carbon dioxide, food fuel, body mass, fossil fuel, waste, sediment, or a material good.3. Next, use the drop-down choices to record what happens to the Energy according to the card. This will be one of the following categories: system of rearranged atoms stores energy, transfers to another place/new system, or released as 'heat'.4. Use the drop-down choices to record the next location you are directed to go to by the system's direction card. In some instances, you will record what happens but remain at that system for another turn. In others, you will record what happens but move on to a new system.5. Record a few details in the notes about what happened to you to remind yourself about important events like being eaten or burned, etc. 6. You will repeat this for 10 rounds, or rolls of a dice[sic]" (Handout Global Carbon and Energy Flow Simulation, page 3). This is an interactive model based on dice rolling and recording data. By rolling the die, they are following a carbon atom's journey and manipulating it as it travels into different systems — atmosphere, ocean, human activity, producers, consumers: herbivores, consumers: omnivores, and soil and rock. They also follow the number of times energy was rearranged, atoms store energy, transfers to another place, and is released as heat and in which system it occurred.

Planning and Carrying Out Investigations

- *Select appropriate tools to collect, record, analyze, and evaluate data* (SEP **3.4**).
    - Lesson 2: In the **Supporting Students in Engaging in Planning and Carrying out Investigations**, teachers are prompted to have students reflect on which method and tool they select for the investigation has differing accuracy and constraints, e.g., carbon dioxide and oxygen probes compared to BTB (Teacher Edition, page 72).
    - Lesson 3: There is an Additional Activity to help students with this element within the lesson. "If you have additional supplies available and/or want to support students in selecting tools to collect data (SEP 3), carbon dioxide probes, flasks or bottles covered with balloons or other methods of capturing carbon dioxide gas, offer students these options here and alter Decomposition Investigation Plan and slide M as needed" (Teacher Edition, page 91). However, because this is an optional activity, not all students may have an opportunity to develop the element through this activity.
    - Lesson 5: The teacher asks questions to help the students consider how the tools selected will be used to collect and record data. "If our independent variable is about the energy from the sun based on Earth's tilt, what can we do in our classroom to simulate that? How can BTB help us measure that change?" (Teacher Edition, page 120).
- *Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated* (SEP **3.5**).
    - Lesson 5: The Hypothesis Development handout prompts students to circle "more, less" for each variable, thereby scaffolding them to make a directional hypothesis.
    - Lesson 8: In this lesson, the term directional hypothesis is introduced, and they practice with the CO2-temperature bottle investigation. "Say, It sounds like you all have some ideas about carbon dioxide being a greenhouse gas that makes the atmosphere hotter, and you have some great ideas for how we could investigate changes in that system. Let students know you have an investigation that you think can help simulate systems with different amounts of carbon dioxide. Provide students with instructions to set up and record data from the investigation on CO2 Temperature Investigation. Talk through the

investigation procedure on slide C and the safety considerations on slide D. Develop directional hypotheses in small groups. Say, In our investigation, we are looking at the relationship between two different variables, carbon dioxide and temperature. Take a moment individually to create a directional hypothesis in your science notebook. What does a hypothesis need to have? What does it mean to be 'directional'? Record their responses on the board" (Teacher Edition, page 176).

- *Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable results* (SEP **3.2**).
    - Lesson 3: Students use an investigation planning tool to plan the decomposition investigation (Teacher Edition, page 90). The questions on the handout prompt students to reflect on how much data they need, but much of the investigation is already laid out (e.g., the number of beakers, the amount of time required to collect each). This investigation does not fully meet this SEP because much of the independent process has been limited.
    - Lesson 5: The Photosynthesis Investigation Plan lays out the investigation step-by-step. Therefore, this investigation is more of a "recipe" type investigation rather than a student-designed investigation where they are provided with a meaningful opportunity to decide how to produce reliable data and results.

Constructing Explanations and Designing Solutions

- *Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables* (SEP **6.1**).
    - Lesson 3: There are questions in the Decomposition Investigation Sense-making document that allow students to make claims between dependent and independent variables. "What patterns do you notice about the decomposition rate of the different barrels over time?... 2. How was the flow of energy different at high temperatures compared to lower temperatures?" (Decomposition Investigation).
    - Lesson 4: Students submit the Electronic Exit Ticket that includes three questions in which they make a claim regarding the relationship between dependent and independent variables (Teacher Edition, page 310).
    - Lesson 8: Students design a data representation to make a claim about CO2 level and temperature. "...and ask students to consider with their groups how to represent, analyze, and explain the results of the data they collected by answering the Making Sense questions on CO2 Temperature Investigation. Display slide F. Provide each group with a large piece of paper or whiteboard and markers to create their representation. Instruct students to share their individual ideas on the Making Sense questions with their groups. Each group should then come to a consensus on how to represent their data and draw their representation. Display slide G. Have students make a claim in their science notebooks based on their group's data representation. Make sure that they support or refute their hypothesis in question 4 of CO2 Temperature Investigation" (Teacher Edition, page 178).
- *Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future* (SEP **6.2**).
    - Lesson 3: Students are supported in developing an explanation based on valid and reliable evidence using the Peat/Permafrost Scaffolded Explanation handout. The

instructions prompt students to use evidence from their investigations and provide a Gotta-Have-It Checklist and Sentence Starters to support explanation construction (Teacher Edition, page 98).

- Lesson 4: In the Geologic Time Reading Section, teachers facilitate a small-group discussion that "support student[sic] in understanding there is only a small different in the angle of the tilt, but the amount of energy from the sun is so substantial it was enough of a difference for that much more solar radiation and sunlight to Earth that it was able to produce that much more matter at that time. If students are unable to notice the subtle difference in the tile from the image in the reading, display slide L. Additionally, since this is a cycle, this change of tilt will happen again in the future. Ensure that the students consider the implications of how the Arctic would be affected again" (Teacher Edition, page 107). Further, in the front matter there is an explanation that this element of connections to the Nature of Science is developed. "In Lesson 4, students come to understand that the amount of solar radiation that hits the surface of the Earth has changed since 10,000 years ago. The increase of the angle of only 2° was enough of a change to increase the amount of energy to hit the surface of the Earth to produce the peat (matter) in the Arctic. Students use this evidence to make predictions of the amount of solar radiation that could be available in the future, as this change in tilt is cyclical" (Teacher Edition, page 17).
- Lesson 6: Students construct an explanation for the anchor phenomenon of Lesson Set 1, zombie fires. "Distribute Zombie Fire Explanation and give students a few minutes to read over the task and ask clarifying questions. Allow students to use their Progress Trackers, Gotta-Have-It Checklists, and science notebooks as resources as they complete the task" (Teacher Edition, page 144). If students need additional support in constructing an explanation, the teacher is provided with suggestions to support student development of this practice in the call-out box on page 144.

- *Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion* (SEP **6.4**).
  - Lesson 5: Students engage in small group sense-making. "2. Explain the results from your investigation, including why those results occurred in terms of changes to carbon dioxide. Make sure to include: why the color changed in any test tube, why the color stayed the same in any test tube, what the color changes tell you about flow of energy and matter in the investigation… Relate your experiment set up to the sun, Arctic, and zombie system throughout Earth's history….Relate your experiment results to the sun, arctic, and peat/permafrost system throughout earth's history" (Photosynthesis Making Sense).
  - Lesson 8: Students participate in a building understanding discussion by comparing case studies that used similar fire management strategies. In a call-out box, teachers are provided with prompts that support students in this element of the practice. "A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence. Your role during the discussion is to invite students to share conclusions and claims and to push them to support their claims with evidence. Students can disagree with each other, and the class does not need to reach consensus on all ideas shared. Areas of disagreement can motivate future investigations. Helpful prompts during these kinds of discussions include: What can we conclude? How did you arrive at that conclusion?

What's your evidence? Does any group have evidence to support Group A's claim? What data do we have that challenges Group B's claim?" (Teacher Edition, page 226).
- Lesson 10: Students discuss their case study and revise their models. "Circulate around the room to formatively assess students' revisions. Bring your class roster and mark off when you hear a student correctly apply scientific reasoning to link evidence from their case study. Responses to Case Studies is a guide summarizing the main points of each case. Use the following prompts with groups: What is happening to the carbon and energy in this ecosystem? How do you know? Wisconsin Case Study (Case 1) and Cultural Burning Case Study (Case 3): How could setting a fire purposely help manage wildfires? What is and is not burning in this method compared to a wildfire? Animal Grazer Case Study (Case 2): What are the cattle eating? Is what the cattle eat the same material that burns during a wildfire? Why are cattle and other grazers important to grassland ecosystems? Trees Case Study (Case 4): Why does planting trees create more resilient forests? What are the impacts to other living things in forests when areas are readily deforested? If students have questions or comments related to power and historicity in the case study, encourage them to record their ideas in their notebook for discussion on Day 3. Encourage questions about quantifying how much must be burned or eaten to have a positive impact to lead into the discussion on day 2 of the lesson." (Teacher Edition, page 216).

- *Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations* (SEP **6.5**).
  - Lesson 11: The teacher prompts students to consider criteria and constraints. "As we think about our community and fire risk, what are the things that need to be protected the most? Why? What are some of the problems that could get in the way? How could we judge our success?" (Teacher Edition, page 242). It's not clear if students will be able consider the trade-offs during this consideration. Another teacher prompt provided in the materials for this discussion is, "How might thinking about perspectives and ideas from various interest holders help us develop criteria and constraints?" (Teacher Edition, page 244).
  - Students use Designing Fire Solutions to generate a solution to fire management (Teacher Edition, page 247). "Now that we have more specific criteria and constraints and know more about these locations, let's try to build some solutions and figure out how we might impact these ecosystems and the interest holders in each community. Display slide L and distribute Designing Fire Solutions and Decision-Making Framework to students" (Teacher Edition, page 247).
  - The home learning activity is an opportunity for students to refine their solution to a complex real-world problem by learning about priorities and trade-off considerations from their community. The teacher is prompted to ask, "How can we ensure that our solutions best fit the communities we care about? Listen for students to imply that they need to check in with interest holders and trusted community members. Send students home with Designing Fire Solutions and instruct them to share their progress in Part 1 with the aforementioned community members. Explain that you will begin the next class by sharing the ideas they gather from the community, then spend time refining and sharing their solutions" (Teacher Edition, page 249).

Disciplinary Core Ideas (DCIs) | Rating: Extensive

The reviewers found extensive evidence that students have the opportunity to use or develop the DCIs in this unit because students are supported to develop competence in the claimed DCI elements as they make sense of the unit phenomena.

LS1.C: Organization of Matter and Energy Flow in Organisms

- *The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.*
  - Lesson 5: Students read about the formation of peat thousands of years ago and the conditions on Earth at that time, then plan and carry out an investigation to generate evidence to support claims about the transfer of energy from the sun to carbon-based molecules in plants. Students then construct an oral explanation for how peat can contain large hydrocarbon molecules. The class constructs an explanation based on evidence for whether or not they think peat would contain large hydrocarbon molecules (like starch) (Teacher Edition, page 127).
  - Lesson 6: One component of the chart students work with is "Plants and atmosphere… Plants interact with the sun, carbon dioxide, water, sugar, and oxygen in the atmosphere…. Carbon dioxide and water are captured using energy from the sun and the mechanism of photosynthesis. The plants store carbon and chemical energy in the sugar (glucose) and release oxygen" (Teacher Edition, page 137).
- *The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.*
  - Lesson 3: "Review the image on the slide, from Lesson 2, that shows that sugar, or glucose, contains carbon, hydrogen and oxygen and that plants, like those in peat, contain glucose" (Teacher Edition, page 88).
  - Lesson 5: Students construct an oral explanation about whether or not they think peat would contain large hydrocarbon molecules (like starch) (Teacher Edition, page 127).
  - Lesson 5: The materials explain the portion of this element that is not addressed in this unit. "Where we are NOT Going...Students will not explore how hydrocarbons are used to make amino acids, proteins or DNA. They will explore these ideas in OpenSciEd unit B.3" (Teacher Edition, page 115). However, the unit materials claim this entire element rather than a part of the element. Students are not provided with the opportunity to develop the second part of the element, "*their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells," in the unit.*
- *As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.*
  - Lesson 3: Optional Banana Investigation — Students examine photos of the decomposition of a banana peel and develop a model that explains the flow of energy and matter in the banana peel system (Teacher Edition, page 87). Because this investigation is optional, not all students may have the opportunity to engage in this activity and develop the targeted science ideas.
  - Lesson 6: The class develops a consensus model by synthesizing what they have figured out so far. They determine that the consensus model must include: "The mechanism of decomposition is cellular respiration, where carbon-based molecules in the peat plus oxygen are converted/rearranged to carbon dioxide, water, and energy. The mechanism of cellular respiration slows down when it is colder and is faster when it is warmer. This

adds more carbon dioxide to the atmosphere when it is warmer" (Teacher Edition, page 137).

- Lesson 9: The class develops a consensus model with different concepts about cycling of matter and flow of energy. "Listen for these ideas: The mechanisms involved in this model include: Photosynthesis pulls carbon dioxide out of the atmosphere, where it can be stored. Cellular respiration releases carbon dioxide from living things into the atmosphere. Wildfires release carbon dioxide from carbon stored in carbon sinks into the atmosphere very quickly. Energy from the Sun is transferred to carbon dioxide molecules in the atmosphere, and this greenhouse effect warms the Earth. Carbon can be stored out of the atmosphere for long periods of time in carbon sinks created by plants. The warming atmosphere increases droughts and thaws permafrost. More droughts lead to more wildfires. The model needs to be generalized for all wildfires and all plant-based carbon sinks. It is difficult to model the amount of carbon dioxide in the atmosphere because it keeps changing and growing. There is a cycle that builds up carbon dioxide over time" (Teacher Edition, page 203).

- *As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy ~~to muscles~~. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.*
    - Note that in the NGSS, the DCI element is, "*As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles*."
    - Lesson 3: Students construct an explanation about why there is so much matter and energy in the zombie fire system. Their explanations need to explain how reduced temperature and oxygen levels affect the mechanism of cellular respiration (Teacher Edition, page 98).
    - Lesson 10: Teachers are prompted to help students build a class model. "After a few minutes, bring the class together. Call on a number of groups to each add one idea to a class version of the model. As groups share, emphasize the importance of adding arrows for cellular respiration to the diagram. Listen for: Both energy and matter are lost to the atmosphere during cellular respiration as molecules of sugar are broken apart to release stored potential energy to grow, reproduce, and move. Cellular respiration also releases heat that warms organisms, but that heat energy flows into the environment along with carbon dioxide and water. Wonderings about how this relates to the amounts of grass, wildebeest, and lions" (Teacher Edition, page 221).

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- *Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.*
    - Lesson 3: "Circulate around the room with an open packet or jar so that students can see the yeast up close. Say, The packet says that it is 'live acting' which means it is actually living. Ask students to share ideas about what it means to be living. Listen for ideas such as: It needs oxygen, water, matter and energy to survive. They reproduce, grow. They produce waste and/or carbon dioxide" (Teacher Edition, page 87). There

may not be an explicit connection between yeast being alive, the process of cellular respiration, and the "why". The teacher asks about yeast as a decomposer and how it interacts with matter and energy. Sample student Responses include: "They rearrange molecules in food into new things in their bodies. It is getting energy from some kind of food that is dead. They use carbon and energy in the sugar to grow" (Teacher Edition, page 87).

  - Lesson 3: Students construct an explanation about why there is so much matter and energy in the zombie fire system. Their explanations need to explain how reduced temperature and oxygen levels affect the mechanism of cellular respiration (Teacher Edition, page 98).
  - Lesson 5: Throughout the lesson, students carry out the Photosynthesis Investigation to explore how the rate of photosynthesis changes under different conditions. The Key Ideas include: "When the energy from the light was more direct, more carbon dioxide was converted into sugar in the plant through photosynthesis. In the Earth's past, the tilt of the Earth was different, which means there was more direct solar energy. During this time period, more plants grew in the Arctic. As the Earth's tilt was reduced, less solar energy was available. Plants died and ice formed, trapping all the matter and energy in the peat/permafrost" (Teacher Edition, page 125). This evidence obliquely supports the second half of this element. However, there is a missed opportunity to help students fully develop the second portion of this element.

- *Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.*
  - Lesson 10: By analyzing four case studies, students conclude that there needs to be a balance of species (including grazing animals and plants) for matter and energy to flow through different levels of places, lands, and waters (ecosystem). Fuel management (through prescribed burns and grazing) helps regulate an overabundance of built-up energy and matter. "Would replanting all the trees in a forest after a fire be enough to restore an ecosystem?...Since the majority of the matter and energy is in the producers and nothing else in the ecosystem can survive without them, it makes sense to start there. It may be necessary to bring in other animals and decomposers to re-establish the cycling of carbon and energy. We do not know if they would come back on their own" (Teacher Edition, page 227).
- *Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.*
  - Lesson 2: After burning peat and other fuels, watching a video, and reading an article, students figure out that peat is made from dead plants, burning peat uses oxygen and releases carbon dioxide. When peat burns heat and light are released and water appears in the system.
  - Lesson 7: Students investigate places, lands, and waters where global carbon sinks are burning with more frequency, using case studies. They analyze how energy, carbon, and matter are moving through different species and kinds and figure out that there are

relationships in the conditions that are making these unrelated locations vulnerable to fire. They develop small group models to help reach consensus on the conditions that make carbon sinks more likely to burn.

- Lesson 9: Students model a simulated carbon cycle. Examples from the lesson include:
  - "Students will work toward the development of a revised complex consensus model on the second day of this lesson. They should be able to use their prior models to explain how the relationships between the components of the carbon cycle could lead to higher temperatures in the atmosphere. Help students move between different scales learned over the course of the unit to connect how small-scale mechanisms like photosynthesis and the growth of individual plants can have global impacts on the atmosphere through the combustion of carbon sinks" (Teacher Edition, pages 191–192).
  - "Introduce the definitions of the carbon cycle and feedback effects below as the need arises in your development of the consensus model. If the need does not arise naturally, point out the looping connections in the consensus model. Say, We co-constructed a couple of new ideas here. You all found these loops in the model. What connected them? Listen for responses such as carbon and energy. Scientists call these loops that pass carbon around in different forms the 'carbon cycle.' Ask students to co-construct a definition of the carbon cycle and add it to their personal glossary" (Teacher Edition, page 204).
  - "Thank you for sharing all of those ideas. We figured out some pretty important things about how humans and fires are affecting the feedback effects for matter and energy in the global carbon cycle. Let's take a moment to record our current understanding" (Teacher Edition, page 207).
- Lesson 12: Students demonstrate their understanding of carbon cycling through Earth's systems utilizing data about carbon dioxide and dissolved oxygen levels and chemical, physical, and biological processes that could account for large fish kills in the Gulf of Mexico each Spring.

PS3.D: Energy in Chemical Processes

- *The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.*
  - Lesson 4: Students read about the formation of peat thousands of years ago and the conditions on Earth at that time, then plan and carry out an investigation to generate evidence to support their claims about the transfer of energy from the sun to carbon-based molecules in plants. This leads to students constructing an oral explanation for how peat can contain large hydrocarbon molecules.
  - Lesson 6: The class develops a consensus model by synthesizing what they have figured out so far. They determine that the consensus model must include: "Carbon dioxide and water are captured using energy from the sun and the mechanism of photosynthesis. The plants store carbon and energy in the sugar (glucose) and release oxygen. Increased solar radiation in the Arctic increased the potential for plants to capture and store chemical energy in carbon-based compounds, using the mechanism of photosynthesis to grow and live."
  - Lesson 12: Students use their understanding of how solar energy is captured and stored in plants through photosynthesis to develop a model of the Gulf of Mexico system that shows how carbon dioxide and oxygen flow through the system.

ESS2.D: Weather and Climate

- *Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.*
    - Lesson 8: Lesson 8 begins to add a forward-thinking lens to the zombie fires phenomena. Here students are figuring out one outcome of what happens to the atmosphere and temperature when so much carbon dioxide is released (Teacher Edition, page 174). Students respond to how a greenhouse works and how to find out large-scale effects of any of carbon dioxide increased concentrations (Teacher Edition, page 175). The CO2-temperature bottle investigation addresses this.
    - Lesson 9: After the investigation in Lesson 8, students analyze historical atmospheric carbon dioxide levels with global temperatures to develop a class consensus model that "more carbon dioxide in the atmosphere increases the greenhouse effect, which warms the Earth more" (Teacher Edition, page 203). "Use the model of Earth's systems (specifically the biosphere and atmosphere subsystems) above to predict what would happen to global atmospheric carbon dioxide if human activity, such as pollution, were to cause a mass die-off of plant[sic]…Explain how an increase in human-caused fires in carbon sinks leads to an increase in temperatures in the global atmosphere" (Teacher Edition, page 338).

ETS.1.C: Optimizing the Design Solution

- *Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.*
    - Lesson 11: Students use a decision-making framework to determine the priority of the criteria the class has generated for determining the effectiveness of their fire management solution. In the Fire Solutions Teacher Reference, it is noted that students will pick two criteria and break them down further and teachers will prompt them to be specific in naming plants and animals for their system (Teacher Edition, page 355).

Crosscutting Concepts (CCCs) | Rating: Extensive

The reviewers found extensive evidence that students have the opportunity to use or develop the CCCs in this unit because, for the length of the unit, there are sufficient claimed CCC elements and significant learning time dedicated to developing and using them.

Systems and System Models

- *Systems can be designed to do specific tasks* (CCC **4.1**).
    - Lesson 10: Students develop a mathematical model to explain how to balance carbon and energy in the system. In the Home Learning Handout, students use the wildliferisk.org/explore website to identify actions that reduce wildfire risks in different systems.
    - Lesson 11: Students split and pair with another group to communicate their fire design solutions and their fire management systems where they sought to do the task of balancing matter and energy (Teacher Edition, page 254).
- *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows—within and between systems at different scales* (CCC **4.3**).
    - Lesson 1: Students develop an initial model to try to explain the zombie fire phenomenon. They are prompted to consider the components of the system and the flow of energy and matter in the system.
    - Lesson 3: The yeast is used to simulate systems. Students are asked what the different components represent in the yeast and beaker model to the zombie fire model.

- Lesson 5: Elodea is used to simulate global photosynthesis trends.
- Lesson 6: Students develop, revise, and use a model that analyzes the inputs and outputs of matter and energy flow in the Arctic ecosystem over time to explain the effect of zombie fires on the release of carbon dioxide into the atmosphere.
- Lesson 9: Students develop a quantitative model to describe the flow of matter and energy in a global fire system.
- Lesson 12: Students must develop a model based on evidence that can be used to simulate the Gulf of Mexico ecosystem and interactions of matter and energy within and between systems (hydrosphere, atmosphere, biosphere).

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 1: Students develop initial models considering "How are energy and matter flowing through these interactions? What can explain what is happening behind the scenes between the components (mechanisms)? What is included as part of the system and what is not? What is outside the zombie fire system?" (Teacher Edition, page 44). The Supporting Students call out box reminds teachers to prompt students to track carbon and energy in the system throughout the lesson (Teacher Edition, page 72).
    - Lesson 3: The Building Understandings Discussion prompts students to build understanding about the "Cold temperatures and low oxygen levels slow the rate of cellular respiration and decomposition. In the peat/permafrost system, organic matter decomposes slowly because it forms under water where there is less oxygen and lower temperatures. Since the peat decomposes so slowly, the carbon (matter/energy) stays in the peat and does not go to the atmosphere as carbon dioxide. When the permafrost thaws, all of that energy and matter is vulnerable to fire and can fuel a zombie fire" (Teacher Edition, page 96).
    - Lesson 5: Students share evidence generated from their investigation such that "When the energy from the lamp was more direct, more energy flowed to the plants, more carbon dioxide from the water was captured by the plants during photosynthesis and converted into sugar" (Teacher Edition, page 123).
    - Lesson 6: "6.B Construct an explanation based on evidence that describes how the biological processes such as photosynthesis and cellular respiration change energy and matter by cycling carbon through and within the systems of the biosphere, geosphere, and atmosphere" (Teacher Edition, page 130).
- *Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems* (CCC **5.3**).
    - Lesson 5: The class constructs an explanation based on evidence for whether or not they think peat would contain large hydrocarbon molecules (like starch) (Teacher Edition, page 127). "What happened to the light energy in the investigation? How did it drive the flow of energy and matter?" (Teacher Edition, page 124).
    - Lesson 10: Students read about successful fire management systems and share takeaways with peers and how each case study addresses the movement of carbon and energy in the carbon sink to plants and animals or atmosphere (Teacher Edition, page 217).
- *Energy drives the cycling of matter within and between systems* (CCC **5.4**).
    - Lesson 2: Students are prompted to consider what tools/measurements they should use/make to determine if energy and carbon dioxide are released from burning peat

and other fuels. Students are prompted to determine if they have evidence that suggests a change in matter or a change in energy when the fuels burned.
- Lesson 5: Students must use evidence from an investigation to show how changing conditions can affect the cycling of matter and the flow of energy in the zombie fire system.
- Lesson 9: In an Electronic Exit Ticket, questions 2, 4, and 6 address energy driving the cycle of carbon within and between the atmosphere and carbon sinks (Teacher Edition, page 337).
- Lesson 10: "After a few minutes, bring the class together. Call on a number of groups to each add one idea to a class version of the model. As groups share, emphasize the importance of adding arrows for cellular respiration to the diagram. Listen for: Both energy and matter are lost to the atmosphere during cellular respiration as molecules of sugar are broken apart to release stored potential energy to grow, reproduce, and move. Cellular respiration also releases heat that warms organisms, but that heat energy flows into the environment along with carbon dioxide and water. Wonderings about how this relates to the amounts of grass, wildebeest, and lions" (Teacher Edition, page 221).

Suggestions for Improvement

Science and Engineering Practices

- Consider strengthening opportunities for students to individually and collaboratively plan and conduct an investigation. The materials could include additional guidance and techniques for teachers to reach this SEP more fully. The materials could reference how students could more independently design an investigation especially if it is not the students first time independently designing an investigation.
- Consider further supporting the development of the SEP: *Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations* by introducing the term "trade-off considerations" and allowing opportunities for students to refine their solutions using student-generated sources of evidence and trade-off considerations.

Disciplinary Core Ideas

- To maintain consistency in the materials, consider striking through the portion of the DCI element: "*The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells,"* that are not developed in this unit.
- Consider using the DCI element wording for **HS-LS1-7** that is the same as the NGSS: "*As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles."* Consider adjusting the wording in the Teacher Edition on pages 15, 83, and 301.

Crosscutting Concepts

Consider explicitly developing CCC **4.1:** *Systems can be designed to do specific tasks* in the learning sequence.

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 and/or designing solutions to problems because there are several events where students are expected to figure something out that requires grade-appropriate elements of each of the three dimensions working together.

Throughout the materials, there are several opportunities in which the students use all three dimensions in order to figure something out. Related evidence includes:

- Lesson 3: The lesson culminates with students constructing an explanation about why there is so much matter and energy in the zombie fire system. In this activity, students integrate the following three dimensions:
  - SEP: **Constructing Explanations and Designing Solutions.** *Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*
  - DCI: **LS1.C.4** *As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.*
  - DCI: **LS2.B.1** *Photosynthesis and cellular respiration (including aerobic processes) provide most of the energy for life processes.*
  - CCC: **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.*
- Lesson 4: Students use the three dimensions to complete the Electronic Exit Ticket. Students integrate the following elements of the three dimensions to complete the task:
  - SEP: **Designing Solutions.** *Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.*
  - DCI: **PS3.D** *The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.*

- CCC: **Energy and Matter**. 5.2 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.*

- Lesson 6: Students use a class consensus model to construct an explanation based on evidence that shows how the biological processes, photosynthesis, and cellular respiration, disrupted by zombie fires account for changes in energy and matter in the cycling of carbon through and within the systems of the biosphere, geosphere, and atmosphere in the Arctic. In this activity, students integrate the following three dimensions:
  - SEP: **Developing and Using Models**: *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.*
  - DCI: **LS1.C.3** Organization for matter and energy flow in organisms: *As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.*
  - CCC: **Systems and System Models**. *They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales.*
- Lesson 9: Students simulate a quantitative model that allows for manipulation to show how a carbon atom moves between the atmosphere, ocean, human activity, producers, consumers herbivores, consumers omnivores, and soil and rock, the seven subsystems representing the five spheres of Earth system. Students record the simulated model using the Global Carbon and Energy Flow Handout. In this activity, students integrate the following three dimensions:
  - SEP**: Developing and Using Models**. *Develop a complex model that allows for manipulation and testing of a proposed process or system.*
  - DCI: **LS2.B.3** Cycles of Matter and Energy Transfer in Ecosystem *Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.* (**HS-LS2-5**)
  - CCC: **Energy and Matter:** Flows and Cycles, and Conservation. *Energy drives the cycling of matter within and between systems.*
- Lesson 11: Student teams design and refine a solution for fire management (based on simpler criteria) for the desired effect of reducing risk and balancing matter and energy in the system. In this activity, students integrate the following three dimensions:
  - SEP: **Constructing Explanations and Designing Solutions**. *Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*
  - DCI: **ETS1.C** Optimizing the Design Solution. *Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed*.
  - CCC: **Cause and Effect**: *Systems can be designed to cause a desired effect.*
- Lesson 12: Students use the dead zones as a transfer task to apply what they figured out about how the flow of energy and matter applies to other systems. They apply their development of focal DCIs, CCCs, and SEPs from the zombie fire and global burning of carbon sinks phenomena towards the dead zone system in the Gulf of Mexico. In this activity, students integrate the following three dimensions:
  - SEP: **Developing and Using Models**. *Use a model based on evidence to illustrate the relationships between systems or between components of a system.* Note that the

student choice portion of writing or drawing may mean that not all students complete a model.

- DCI: **LS2.B** *Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes; The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.*
- CCC: **System and System Models**. *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.*

Suggestions for Improvement

None.

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 lesson builds directly on prior lessons and makes the links explicit to students. The unit includes several tools to help students make these links including time for students to reflect on past lessons at the start of each lesson, support to generate questions to drive the learning forward, and nested phenomena that build towards making sense of zombie fires and global fire management. Students develop proficiency toward all targeted PEs.

Each lesson builds on each other by addressing questions raised in those lessons, cultivating new questions that build on what students have figured out, or cultivating new questions from related phenomena, problems, and prior student experiences. Related evidence includes:

- The DQB is developed in Lesson 1 and used to brainstorm questions, investigations and sources of data that could help figure out the phenomenon — zombie fires. Students return to the DQB in Lessons 2, 6, 7, 9, 10 and 11 to add questions or to determine which questions have been answered. This routine links the lessons from the perspective of the student. Related evidence includes:

- Lesson 1: Students stop and jot down questions after developing initial models. These questions are used along with others to create the DQB. Between Day 1 and Day 2 of the lesson there is another opportunity for students to record questions for the DQB. “Let the class know that at the next session we will share all of our questions and build a DQB to help figure out what is going on with zombie fires” (Teacher Edition, page 51). The class creates the DQB and decides on a main question to investigate first. “Once everyone has contributed to the DQB, ask, Can we articulate a main question that we will answer by investigating all these questions? Listen for ideas such as, How can fires burn under ice and release so much carbon?, What causes zombie fires to burn?, or What causes fires in ecosystems to burn? When a potential driving question arises, repeat it aloud, and ask, Do you think that by answering this question, we will have answers to most of the questions on our Driving Question Board? Look for agreement using a show of hands, and then write the chosen question at the top of the DQB with a chart paper marker” (Teacher Edition, page 53).
- Lesson 6: “Revisit the Driving Questions. Distribute 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 slide Q. We did not answer this question or any parts of it yet: Our class answered some parts of this question, or I think I could answer some parts of this question: ✓. Our class answered this question, or using the ideas we developed, I could now answer this question: ✓+” (Teacher Edition, page 146).
- Lesson 7: “Add questions to the DQB. Display slide Z. Say, So we now understand some of the places where carbon sinks are burning around the world and what is making them more likely to burn. What new questions do you have? Provide sticky notes for the students to write new questions. Ask them to share questions out loud as they add them to the DQB” (Teacher Edition, page 166).
- Lesson 9: “Throughout the discussion, and again toward the end, remind students to record any questions they have in their science notebooks so that they do not lose those questions. They will have a chance to add them to the DQB at the end of class” (Teacher Edition, page 201). “Are there any questions from our DQB or ideas from our Related Phenomena poster that we want to revisit at this time?” (Teacher Edition, page 207).
- Lesson 10: “Motivate discussion of solutions to stop fires. Display slide C. Ask students to recall the case studies they read about in lesson 7 and the possible solutions they came up with for those scenarios. Direct them to revoice questions from the DQB or Fires Progress Tracker about ways to manage or reduce carbon sinks” (Teacher Edition, page 214).
- Lesson 11: “Have students take out the document DQB Questions in Lesson 6 and provide them with an updated version if you made one. Have students work in pairs for 5 to 10 minutes to mark questions they think the class has answered using the symbols on the handout, replicated here. Additionally, have students choose three questions to answer with evidence from their science notebooks” (Teacher Edition, page 256).

- The navigate section of the lessons supports teachers in centering student learning and prompts students to return to figuring out the phenomenon regularly.
  - Lesson 1: “Say, Last class, we brainstormed a lot of questions about how zombie fires could be burning under ice and releasing carbon dioxide. Today, we are going to post zombie fire questions to our Driving Question Board and begin thinking about how we are going to investigate what is happening in the system or what causes zombie fires to

happen. If you collected student questions at the end of the last class, pass them back now" (Teacher Edition, page 51).

- Lesson 2: The navigate section suggests students reflect and share out on questions such as what they figured out about burning zombie fires in the Arctic last class and that next steps are figuring out more about permafrost and how peat can burn under ice (Teacher Edition, page 64).
- Lesson 3: The navigate section helps students link their learning from last time about peat and permafrost to new questions about peat (Teacher Edition, page 84). The sample student responses here are very open-ended, reflecting what is towards the beginning of the unit, but it may take some maneuvering to truly have these student questions drive the learning in Lesson 3.
- Lesson 4: The navigate section prompts the teacher to problematize the presence of peat in the Arctic to help students generate questions around why there is so much plant matter in a cold and snowy location (Teacher Edition, page 103). While this centers the phenomenon and keeps student learning focused on figuring it out, it does require significant teacher guidance to keep the students learning in this direction.
- Lesson 5: In the Learning Plan for Lesson 5 section, Earth's tilt is reviewed which is a sub-phenomenon that is scaffolding students towards figuring out what led to the peat accumulating in the Arctic and connecting the last lesson to the need for an investigation (Teacher Edition, page 116).
- Lesson 6: As students pause in Lesson 6 to come to consensus around what they know about zombie fires as carbon sinks that are releasing so much carbon dioxide through burning, the three dimensions are clearly linked and in service of figuring out the phenomena — drawing models and communicating ideas with others to explain the concepts (Teacher Edition, page 134).
- Lesson 7: Teachers are prompted to draw out student responses relating to curiosity about investigating other places in the world where fires are happening. This is teeing up the learning in Lesson Set 2 that connects the phenomena in Lesson Set 1 with related sub-phenomena and global connections (Teacher Edition, page 155).
- Lesson 8: Lesson 8 begins to add a forward-thinking lens to the zombie fires phenomena. Here students are figuring out one outcome of what happens to the atmosphere and temperature when so much carbon dioxide is released (Teacher Edition, page 174).
- Lesson 9: Students are supported in linking the CO2-temperature bottle investigation results they carried out in Lesson 8 into the analysis of global temperature trends to help figure out the same sub-phenomena. What is the result of the burning of carbon sinks (Teacher Edition, page 191).
- Lesson 10: This navigate section again centers student responses and questions to figure out the phenomena, how to manage carbon sinks and in this case, learning from people who are doing that (Teacher Edition, page 214). "Ask three students to share a generalized reflection on what they figured out today with the class using the slide prompts. Focus on the cycling of carbon and energy for this conversation, holding analysis of other parts of the technique until discussion on day 3. Listen for students to mention that: Two case studies involve burning on purpose to reduce the size of the carbon sink. Three of the case studies involve removing plant material to prevent fire. One involves planting to restore trees and sequester carbon. Reflect on new ideas. Display slide H. Provide a minute for students to silently reflect on the prompts on the screen. How do you feel about what you learned from these case studies? What

questions do you have about the effectiveness of these management techniques" (Teacher Edition, page 217).
    - Lesson 11: This section includes a strategy to have students share home learning and bring in their own experiences and ideas relating to the phenomena of fire management (Teacher Edition, page 241).
    - Lesson 12: Student ideas do not drive this section. This lesson is satisfying the need for a transfer task and demonstration of understanding of the unit key concept.
- The Progress Tracker is used throughout the unit to help students record their thoughts on the phenomenon. Students update the Progress Tracker in Lessons 1, 2, 5, 6, 7, 9, and 10. For example:
    - Lesson 1: The Progress Tracker is introduced. "Propose starting a Progress Tracker to keep track of ideas. Say, As we are looking at our initial models, the questions we had, and the ideas for investigations we thought of so far, it is also clear there are many things that we have already started to figure out, and we did not yet get a chance to add them to our Progress Trackers. Let's take some time to do that now, and it will also refresh our memories so we can get a productive start on some of these investigation ideas today" (Teacher Edition, page 56).
    - Lesson 2: The students update their Fires Progress Trackers while the teacher displays slide U. Teachers prompt students to bring up questions related to the five dimensions of the complex-social ecological framework (Teacher Edition, page 77).
    - Lesson 7: "Say, What are the key takeaways from the lesson that we need to keep track of? Add in some of the possible solutions you think may work as questions. Complete a new row in Fires Progress Tracker. See Progress Tracker Key for sample progress tracker ideas" (Teacher Edition, page 166).
    - Lesson 10: The Progress Tracker is used to connect ideas to related phenomena. "Share wonderings from other case studies and related phenomena. While we are talking about challenges of doing collaborative cultural burns like the one in Victoria, let's share more about the wonderings we had from the other case studies and questions they sparked about related phenomena. Display slide AA. Make sure the Related Phenomena poster from Lesson 1 is visible. Also, repost the chart of wonderings made on Day 1 and add to it. Encourage students to look back at the case studies they read along with Fires Progress Tracker to find ideas to add to the discussion" (Teacher Edition, pages 229–230).
    - Lesson 11: "Say, Last class, we updated our Progress Trackers, but it has been a while since we have reviewed what we have figured out. What else have we figured out that helps us explain 'What causes zombie fires to burn under the ice and what are the consequences?' Direct students to revisit their Fires Progress Tracker rows from previous lessons and discuss with a partner, then complete the four columns in this lesson's Fires Progress Tracker section. See Progress Tracker Key for sample progress tracker ideas" (Teacher Edition, page 256).

The lessons help students develop proficiency in the following targeted set of PEs. The materials cite the following PEs as "building towards" (Teacher Edition, page 1):

- **HS-ESS2-6**: *Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.*
- **HS-ESS3-6**: *Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.*

- **HS-ETS1-2**: *Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*
- **HS-LS1-5**: *Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.* **HS-LS1-6**: *Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules*.
- **HS-LS1-7**: *Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in the new compounds are formed resulting in a net transfer of energy*.
- **HS-LS2-3**: *Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.*
- **HS-LS2-4**: *Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.* **HS-LS2-5**: *Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.*

Suggestions for Improvement

- When student questions are intended to drive the learning at the beginning of Lessons 3 and 4 to connect related sub-phenomena, consider including additional support or pathways for how to meaningfully address student questions that may veer in a different direction than the planned learning sequence.
- Consider providing additional guidance for teachers in the "Navigate" section of Lesson 3. Currently, the only guidance is to "Stop and Jot new questions" (Teacher Edition, page 98) and the materials list the DQB. This is an opportunity to provide teachers with additional support to wrap up ideas and questions from Lesson 3 relating to matter and energy in the zombie fire system and to link to the focus of Lesson 4, exploration of how so much plant material came to be in the Arctic in the form of peat.

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 the materials identify the focal DCIs across many domains — life, physical, and

Earth and space science and engineering, technology and the application of science. CCCs are not explicitly used to make connections across the science domains.

DCIs from different science domains are used together to explain phenomena. The materials claim life science, physical science, and earth science DCIs as being focal in the unit. (See Criterion I.B for further evidence). Some examples of connections where they are used together include:

- Lesson 4: There are connections between solar radiation in the Arctic and the potential for plants to capture and store chemical energy in carbon-based compounds, which connects to ecosystems and flows of matter and energy in the ecosystems in photosynthesis.
- Lesson 9: Earth Science and Life Science ideas are used to understand how human activities have altered the amount of carbon dioxide in the atmosphere and how that impacts biotic and abiotic factors.
- Lesson 12: Students complete a transfer task where they consider nitrogen and oxygen cycles in the transfer task.

There are callouts for specific instances where the teacher should be mindful of how CCCs are useful and developed. However, there are missed opportunities to point out CCC use across science domains. Related evidence include:

- Lesson 2: As students are developing initial models, they are directed to “focus first on the components or parts of the system and go through some of the categories they identified on *Arctic Fire Noticings/Wonderings.* Next ask them how these components are interacting with each other in zombie fires” (Teacher Edition, page 44).
- Lesson 5: In the Where We Are Going Section, the materials point out to teachers that as students work towards developing **HS-PS3.D** and **HS-LS1,** they will develop and use elements of the CCC **Matter and Energy** to focus on energy from the sun driving photosynthesis and helping figure out the energy available in the phenomena of zombie fires (Teacher Edition, page 115). There is a missed opportunity to point out this CCC use across science domains to students.
- Lesson 6: There is a callout for supporting students in developing and using **System and System Models** (Teacher Edition, page 140) during a class consensus model. While students are working towards a lesson-level performance expectation (LLPE) that connects life science and physical science ideas as energy and matter move through the peat and permafrost zombie fire system (Teacher Edition, page 138), the use of this CCC across domains is not explicitly pointed out to students.
- Lesson 9: The call out box explains “this lesson has students modeling systems and multiple scales and across ESS and LS domains as they describe the flow of matter and energy from the molecules scale systems…to global scale systems” (Teacher Edition, page 191). The CCC use across science domains is not explicitly pointed out to students.
- Lesson 12: Students use **Matter and Energy** to make sense of the dead zones in the ocean as part of the transfer task. This connects domains of life science and Earth science with connections to the hydrosphere and levels of oxygen and nitrogen in the water. “Create a revised model below using words and/or drawings. Be sure to include: The steps leading to low dissolved oxygen and dead zones. The roles of phytoplankton and bacteria. The inputs and outputs of photosynthesis and cellular respiration (include the flow of both matter and energy). The role of the Sun and excess Nitrogen in the water. The effect of low oxygen on shrimp and fish and why this is the effect. Where the dissolved oxygen went and how it got there” (Assessment Dead Zone Transfer). The CCC use across science domains is not explicitly pointed out to students.

Suggestions for Improvement

- Consider providing explicit opportunities for students to use CCC elements to make connections across science domains to students.
- Consider an individual reflection opportunity for students to consider how **System and System Models** is helpful for constructing the consensus model in Lesson 6, potentially in the reflection in Step 5.

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. The materials explicitly state mathematics and ELA standards and students use ELA skills throughout the unit to further sense-making. Students use graphs in instances where mathematics skills aid in sense-making. In several instances/lessons, students use reading skills to develop understanding and explanations of the phenomenon of zombie fires. However, there is a disconnect between some of the claimed ELA and mathematics standards and what actually occurs in the lesson, which may hamper student understanding of the connections between content areas.

Students have opportunities to read, write, listen, and speak throughout the unit and use a variety of texts including case studies, articles, and graphical representations of information. There are opportunities for scaffolding within the unit. Some examples include:

- Lesson 1: Students look at graphical representations of information in the inquiry slides to fill out a graphic organizer about zombie fires.
- Lesson 2: The “Peat [sic] Permafrost, Carbon” reading has an infographic showing the formation of peat between 1 year and 1,000 years. Students use this as well as the attached article to record noticing, wonderings, and plan an investigation.
- Lesson 3: Students have the opportunity to write an explanation and revise it. “Distribute Peat/Permafrost Scaffolded Explanation to each student. Describe how to use the questions and sentence starters as support. Collect the explanation from each student and evaluate using Explanation Feedback Guidance. Provide students with an opportunity to revise and respond to your comments on Explanation Feedback Guidance by rewriting their explanation before they use this explanation in Lesson 6” (Teacher Edition page 98).
- Lesson 6: Students listen as they complete a class discussion. “Continue adding components, interactions, and mechanisms. Display slide K. Encourage students to add and build on each other’s ideas until the class is confident in their model… Asking students to restate what another student has said supports the goal of students listening carefully to each other so that they can

work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this" (Teacher Edition, page 140).

- Lesson 7: Students have different case studies: Tonlé Sap Carbon Sink (Cambodia), California's Carbon Sink, Cerrado Carbon Sink (Brazil), Victoria Carbon Sink (Australia) and Great Dismal Swamp. "Students obtain information from case studies compiled from several journal articles and other peer reviewed sources that showcase critical information about carbon sinks that are burning from several different causes. They evaluate the information from the case studies with making sense questions that help them to compile their ideas and look at the system from several perspectives" (Teacher Edition, page 158).

There are mathematics and ELA standards stated in the lessons that are used by students. The standards claimed are at grade level. Some claimed standards do not match up with what students are doing in the lesson or because some activities are done in groups, some students may not fully engage with the claimed standard. Related evidence include:

- Mathematics standards are called out in Lessons 8, 9, 10, and summarized in the unit overview. Students use mathematics skills to explain or help understand the scientific concepts, phenomena, or results.
  - **CCSS.MATH.CONTENT.8.F.B.5** *Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.*
    - This standard is listed as a prerequisite (Teacher Edition, page 22).
    - Lesson 8: Students make a graph to describe qualitatively the relationship between CO2 and temperature from their investigation (Teacher Edition, page 178).
    - Lesson 9: Students analyze a graph comparing historical atmospheric carbon dioxide levels with global temperature and use a qualitative model to simulate carbon and energy flow in Earth's systems (Teacher Edition, page 191).
    - Lesson 10: "MP.4. Model with Mathematics" (Teacher Edition. Page 233). Students choose proportions and justify those proportions in their "Model Scaffold." This is done in groups of two to three students. Some students may not have the opportunity to fully participate in this practice as there is not an independent portion.
  - **CCSS.MATH.CONTENT.HSN.Q.A.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 8: Students develop directional hypotheses as part of the CO2-temperature bottle investigation, identify variables, and graph and interpret the data (Teacher Edition, page 183).
  - **CCSS.MATH.CONTENT.HS.N-Q.2** *Quantities: Reason quantitatively and use units to solve problems. Define appropriate quantities for the purpose of descriptive modeling.*
    - Lesson 9: Students use descriptive modeling by aggregating their matter and energy data collected from visiting each subsystem into tables and comparing the number of times a subsystem was visited, the type of carbon-based molecule, length of time in that type/system, as well as indicators of energy and number of occurrences (Teacher Edition, page 208).
- ELA standards are claimed and called out for teachers in Lessons 1, 3, 4, 5, 6, 7, 9, 10, and 11. Students use reading skills to develop understanding and explanations of the scientific concepts, phenomena, or results.

- **CCSS.ELA-LITERACY.RI.9-10.10** *Range of Reading and Level of Text Complexity: By the end of grade 9, read and comprehend literary nonfiction in the grades 9–10 text complexity band proficiently, with scaffolding as needed at the high end of the range.*
  - Lesson 1: "Students obtain information from reading nonfiction texts in the Arctic Fire Noticings/Wonderings and Arctic Fire Visual Inquiry"(Teacher Edition, page 58). Students read a nonfiction text *Arctic Fires* and then complete a visual inquiry. After each activity students are prompted to share their noticings and wonderings about zombie fires. However, there is very little text on the inquiry slides and some domains are focused almost exclusively on photographs and simple phrases such as "Places, Lands, and Water" and "Species, Kinds, and Behaviors."
- **CCSS.ELA-ELA.Literacy -RST.11-12.1** *Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.*
  - Lesson 2: "Students use *Peat, Permafrost, Carbon* to distinguish between peat and permafrost and to understand the steps in peat formation" (Teacher Edition, page 78). Students do not specifically attend to distinctions the author makes and to any gaps or inconsistencies in the account.
- **CCSS.ELA-LITERACY.WHST.9-10.9** *Draw evidence from informational texts to support analysis, reflection, and research.*
  - Lesson 4: In the Additional Lesson 4 Teacher Guidance, the materials state, "Students use images and a reading as informational text to analyze and reflect on how changes in the Earth's tilt could affect the amount of solar radiation received in the Arctic" (Teacher Edition, page 109). Throughout the lesson, they read a Geologic Time handout, analyze reference photosynthesis data images, and perform a card sorting activity.
  - Lesson 5: In the Additional Lesson 5 Teacher Guidance, the materials state, "Students use images and a reading as information text to analyze and reflect on how changes in the Earth's tilt could affect the amount of solar radiation received in the Arctic" (Teacher Edition, page 128). However, the students do not have a reading or images to analyze and reflect on in Lesson 5.

- Students use writing skills to explain and communicate their understanding of the scientific concepts, phenomena, or results.
  - **CCSS.ELA-LITERACY.WHST.9-10.2** *Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.*
    - Lesson 1: There is an opportunity stated for cross-curricular collaboration as they gather stories from their families and communities about impacts of wildfires. "Consider creating a digital space, like a post in google classroom or a Flipgrid link, where students can share the fire stories from others on Day 2. If most or all students know someone with an experience to share, this is also a great opportunity to collaborate with an English Language Arts teacher for students to create expository texts using Common Core standards such as CCSS.ELA-LITERACY.W.9-10.2 or CCSS.ELA-LITERACY.W.9-10.3" (Teacher Edition, page 42). This is an alternate activity. Some teachers may choose not to do this, and it would lessen the powerful connections between ELA and science.
    - Lesson 3: "Students use evidence from their investigations to write explanations about the flow of energy and matter through decomposition and cellular respiration to explain why so much peat remains in the environment" (Teacher Edition, page 98).

- **CCSS.ELA-LITERACY.W.9-10.4** *Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.*
    - Lesson 6: Students produce a final explanation of what is happening in zombie fires burning under the ice to release so much carbon at the end of this lesson set (Teacher Edition, page 148).
- **CCSS.ELA-LITERACY.RST.9-10.2** *Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide accurate summary of the text.*
    - Lesson 7: Students read an article together and piece together central ideas to create an explanation to share with the rest of the class (Teacher Edition, page 167).
    - Lesson 10: Students read the case studies in a jigsaw manner, summarize the information to present and convey the central ideas to their peers (Teacher Edition, page 232).
- **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 9: Students build a quantitative model using written information about carbon atoms. They then use the data collected in the quantitative model to write the journey of their carbon atom (Teacher Edition, page 208). The quantitative aspect of the dice rolling is used to generate data based on the cards, and it may not be explicitly clear to students why this type of representation is helpful.

- Students use speaking and listening skills to explain and communicate their understanding of the scientific concepts, phenomena, or results.
    - **CCSS.ELA-LITERACY.SL.9-10.4** *Present information, findings, and supporting evidence clearly, concisely, and logically so that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.*
        - Lesson 11: Students present their fire management solutions in jigsaw groups and small groups (Teacher Edition, page 257).

Suggestions for Improvement

- Consider providing opportunities to support students to better understand connections between science and other content areas.
- Consider additional formats for students to read such as fictional or narrative stories, news articles, journal articles, infographics, and websites of scientific entities.
- Consider a closer alignment of claimed ELA and mathematics standards and what is done in the lessons.
- Consider ensuring that all students are provided with the opportunity to develop and use all claimed ELA and mathematics standards, especially during group activities.

OVERALL CATEGORY I SCORE: 3 (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 because students experience phenomena as directly as possible. The materials include suggestions for how to connect instruction to students' communities, and teachers are directed to support their students in making connections from their learning to their lives. There are two primary related phenomena that students make sense of: zombie fires and the burning of global carbon sinks. The materials bridge any potential disconnect between students' lives and the faraway phenomena of zombie fires by bringing in the larger phenomena of burning of global carbon sinks. The materials approach this in a nuanced and sensitive manner by introducing students to the people around the world who are impacted by the burning of carbon sinks and who manage wildfires through cultural practices. Quality representations are used in the materials when direct observation is not possible. There are explicit connections to make the phenomena relatable through the at-home learning and connecting zombie fires to other case studies of fires as well as community experiences around fires.

Students experience the phenomenon as directly as possible. Related evidence includes:

- Lesson 1: Students notice and wonder out load as they observe images related to the zombie fires. "Navigate and introduce the zombie fire phenomenon. Display slide A. Say, NASA scientists were flying over areas near the Arctic Circle and noticed something interesting. In areas where there had been forest fires the previous fall, scientists noticed there were new fires burning very close to where the old fires had been. When scientists look at land that was previously burned and damaged by a forest fire, they call what is left over a burn scar. This image shows 2 burn scars from fall 2015 and an active wildfire in spring 2016. Ask students to notice and wonder out loud with the class about the burn scar image. Read about Arctic Fires. Display slide B. Acknowledge student noticings and wonderings and then distribute Arctic Fires. Have students read and annotate (using whatever strategy is in place in your school/classroom)" (Teacher Edition, page 35).
- Lesson 1: "Conduct a visual inquiry of the zombie fires. Display slide G. Divide students into groups of 3-4. For each group, provide a device with access to the Arctic Fire Visual Inquiry Zombie Fire Visual Inquiry. Allow students to work together to obtain information from the slides dedicated to each dimension" (Teacher Edition, page 38).

- Lesson 2: Students complete a lab where they burn different fuels and gather data to use to connect to the phenomena of zombie fires and peat. "Burn fuel samples using the instructions provided in Burning Fuel Samples. Have students record their observations in their science notebooks for each fuel burned. They should record observations for what they suggested, for example, changes in BTB color, changes in temperature, and differences in relative measurements across the samples" (Teacher Edition, page 74).
- Lesson 3: Students plan and carry out an investigation using yeast as a decomposer. "I have a decomposer that is safe to use in our classroom, easy to get a hold of, and could help us investigate what happens to matter and energy during decomposition in a short period of time. Hold up a packet of yeast…" (Teacher Edition, page 87).
- Lesson 5: Students plan and carry out an investigation using Elodea. "Say, I have some materials that we can use for our investigation. Display slide F and show students the available supplies. Let them know that you have found a plant that they can use that lives in water that will give us an opportunity to use BTB in our investigation" (Teacher Edition, page 119).
- Lesson 7: "Introduce the case studies. Display slide H. Explain that you have five case studies that include photographs and data collected from the different locations they identified on the map that present ideas about carbon sinks that are burning around the world: Western United States (California), Southeastern United Stated (Great Dismal Swamp), Australia (Victoria), Brazil (the Cerrado), and Cambodia (Tonlé Sap Lake, Cambodia)" (Teacher Edition, page 157).
- Lesson 8: Students conduct an investigation with a heat lamp to simulate systems with different amounts of carbon dioxide.
- Lesson 10: Students look at four case studies about fire management. "Distribute one of the following to each student based on their group: Prescribed Burn Case Study, Grazing Case Study, Cultural Burn Case Study, or Tree Planting Case Study" (Teacher Edition, page 215).

Students have multiple opportunities to connect the phenomenon they figure out to their own prior experiences, community, or culture. Related evidence includes:

- Lesson 1: "Home learning is an important place to do cultural formative assessment" (Teacher Edition, page 249).
- Lesson 1: During the "Initial Ideas Discussion" the teacher is prompted to ask, "How have your experiences helped you connect to zombie fires?" (Teacher Edition, page 40). "In addition to recording their own experiences, students should ask at least one person from their family or community if they have ever been impacted by wildfires or other fires, and if so, ask them the questions on Fire Connections Home Learning. If students identified a trusted adult earlier in the lesson, encourage them to connect with that person as they engage with the home learning. Tell students, Keep track of your interviewees' ideas on the handout or on a piece of paper in your notebook so that you can share them with your classmates the next time we are together. If you have an experience you feel comfortable sharing, please write your responses down as well" (Teacher Edition, page 42).
- Lesson 3: The teacher is provided guidance to connect students' initial ideas about decomposition to their experiences. "We read that peat is formed from plants that do not completely break down. What do you know about how matter like plants breaks down?... What do we already know from middle school or our lived experiences about the process of living things breaking down other living or dead things?" (Teacher Edition, page 85).
- Lesson 6: "Attending to Equity UDL: Framing students' families and communities as legitimate funds of knowledge can serve multiple purposes…" (Teacher Edition, page 232).
- Lesson 7: Students investigate case studies. There is a note in the margins to help teachers connect case studies to the student's cultures and past experiences. "Additionally, if students

have lived or traveled to other countries, invite them to relate these case studies to their lived experiences" (Teacher Edition, page 158).

- Lesson 8: "Acknowledge the Indigenous past, present, and future of case study locations…Add a land acknowledge for the land your school sits on using the information at…" (Teacher Edition, page 228).
- Lesson 10: There is an opportunity to connect fire risk to the students' community. "Investigate fire risk in the community near your school. Display slide BB and distribute Fire Risk Home-Learning to each student. Make sure pairs of students have access to an internet-connected device. Demonstrate how to do steps 1-4 on Fire Risk Home-Learning at the front of the class, using the area around your school. Then provide time for students to investigate a community they are concerned about as they complete steps 1-4 with their partner….How does the risk in your community compare to other places…What techniques might work to reduce the risk of fire in your community?" (Teacher Edition, pages 230–231).
- Lesson 11: Students talk about their at-home learning, and this drives the fire management solution planning. "What concerns you and others in your community most about the fire risk? Consider human and more-than-human members of the community. Who are the knowledge holders we should consult in this community when planning to reduce fire risk? What should we ask them? What should we be asking or telling the people in power who currently make decisions about managing fire risk?" (Teacher Edition, page 241).

The materials provide support to teachers for anticipating issues that may arise when students communicate about their lives outside of school. There are opportunities to connect the phenomena to similar phenomena that are more closely tied to the students' lives. Related evidence include:

- Lesson 1: "Additional Guidance - Before the start of the unit, consider letting students know that the class will be discussing fires to give them time to process and raise any concerns they have. Be mindful that sharing or hearing stories of past fires can bring up past or recurring trauma for students. It is advisable to send home communication to parents, letting them know the subject of the lesson in advance so they can inform you of any topics that may be sensitive for students" (Teacher Edition, page 34).
- Lesson 1: Teacher Reference: The Trauma-Informed SEL Supports are thorough and specific . The support documents are very specific to the unit, rather than simply acting as a general summary of trauma-informed practices and SEL considerations. For example, they reference the specific difficulty students may have as they deepen their understanding of climate change, including zombie fires, and its impact on people across the globe (Teacher Edition, page 281). The tools describe best practices in trauma-informed approaches as well as specific activities teachers can do with students to "Check, Reflect, Connect."
- Lesson 3: There is guidance to connect initial ideas about decomposition to students' experiences. "We read that peat is formed from plants that do not completely break down. What do you know about how matter like plants breaks down?... What do we already know from middle school or our lived experiences about the process of living things breaking down other living or dead things?" (Teacher Edition, page 85).
- Lesson 6: "Focus on social and emotional learning. Display slide I. Say, during this investigation of how fire is displacing people and organisms and changing whole ecosystem you might have different feelings, and feelings with varying intensity" (Teacher Edition, page 158).
- Lesson 7: In the Navigate Section, additional guidance is provided acknowledging that students may have difficult emotional states, experiences, or feelings related to wildfires. The resources acknowledge this connection in students' lives and provide resources for teachers to use to support these feelings (Teacher Edition, page 154).

- Lesson 10: "While making a land acknowledgment is good practice, it is only a first step in acknowledging the damage done to communities by settlers. These words are empty without tough conversations and action. Learn more about making Indigenous land acknowledgements here: https://nativegov.org/news/a-guide-to-indigenous-land-acknowledgment/" (Teacher Edition, page 228).
- Lesson 11: The materials note in an Attending to Equity call-out box that "There are instances where the classroom community does not represent the larger community. If this is the context in which your students are working, it is imperative that you guide your students in taking inventory of the many groups that could be impacted by their solutions, especially the marginalized groups in the areas that they have a connection to prevent the unintentional perpetuation of oppressive systems when developing their solutions" (Teacher Edition, page 247).

Suggestions for Improvement
None

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 students have several opportunities to clarify their own ideas and compare to new ideas encountered throughout the unit. Through the iterative process of developing models to explain the zombie fires phenomenon students refine their models using feedback from class discussions and the teacher, often orally.

Classroom discourse includes explicitly expressing, clarifying, and justifying student reasoning. Students have opportunities to share ideas with peers directly, to elicit ideas from others, and to use others' ideas to improve or change their own thinking. The teacher has sufficient support to act as an expert facilitator to draw out student ideas. The support is specifically customized to the lesson materials. Related evidence includes:

- Students have multiple opportunities to clarify, justify, interpret, and represent their ideas in small group and whole class discussions. Students also represent their ideas in writing. For example:
  - There are many examples where students do a "turn and talk" with a partner to share their ideas. These opportunities for partner talk occur in nearly every lesson.
  - Lesson 6: Teacher Reference Discussion Mapping Tool: The tool allows the teacher and students to reflect on patterns of class dynamics. To complete the discussion mapping tool, the teacher writes student names around a circle on paper according to where they are sitting in the room, then one or more student recorders chart the progression

of the conversation by drawing lines from student name to student name and using the mapping codes (e.g., C-claim given, E-gave evidence, OT-off topic) (Teacher Edition, page 320).

- The Progress Tracker is used throughout the unit to help students record their thoughts on the phenomenon. Students update the Progress Tracker in Lessons 1, 2, 5, 6, 7, 9, and 10. Students can use their Progress Trackers when working on the Zombie Fire Explanation assessment in Lesson 6. The Progress Tracker is used as an artifact for students to see how their thinking has changed over time. For example:
    - Lesson 1: The Progress Tracker is structured to show thinking over time. There is a box at the top for students to record Unit Driving Question(s). There are rows for students to record updates when prompted in the unit. The columns include "What we figured out (WWFO), How does WWFO help us make progress on our driving Question about zombie fires?, How does WWFO connect to me or my community, or have a larger scale impact?, and What Questions do I have now?" (Fires Progress Tracker).
    - Lesson 1: "Propose starting a Progress Tracker to keep track of ideas. Say, As we are looking at our initial models, the questions we had, and the ideas for investigations we thought of so far, it is also clear there are many things that we have already started to figure out, and we did not yet get a chance to add them to our Progress Trackers. Let's take some time to do that now, and it will also refresh our memories so we can get a productive start on some of these investigation ideas today" (Teacher Edition, page 56).
    - Lesson 2: The students update their Fires Progress Tracker while the teacher displays slide U. The teacher prompts students to bring up questions related to the five dimensions of the complex-social ecological framework (Teacher Edition, page 77).
    - The Progress Tracker Key provides guidance and samples for the types of ideas that could be recorded.
    - Lesson 6: Students are allowed to use their Progress Trackers as they complete the *Zombie Fire Explanation* task (Teacher Edition, page 144).
- The teacher facilitates an "Initial Ideas Discussion" in Lessons 1, 2, 3, and 4. "Reasons for eliciting students' initial ideas include: To get students' prior knowledge and experiences on the table. To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others). To help students realize that there are gaps in our understanding in order to promote curiosity and consider what we could do next to figure something out" (Teacher Edition, page 40). Examples of strategies and teacher guidance include:
    - Lesson 1: "Facilitate an Initial Ideas Discussion about what we notice and wonder about the zombie fires. Call on a few student pairs and ask them to share their ideas. Record these ideas on the whiteboard. Encourage students to build on each other's ideas using prompts such as, Did any pair discuss similar ideas? Or Who can build on this idea?" (Teacher Edition, page 40).
    - Lesson 2: "Discuss observations. Display slide R. Ask, Now that we have burned the fuels, what have we figured out? Give students a minute to think independently and then share with a partner or group before discussing it as a class" (Teacher Edition, page 75).
- The teacher facilitates a "Building Understandings Discussion" in Lesson 2, 3, 5, and 8. Strategies and examples of teacher guidance include:
    - Lesson 2: "STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence.

Your role during the discussion is to invite students to share conclusions and claims and to push them to support their conclusions and claims with evidence. Helpful prompts during this kind of discussion include…" (Teacher Edition, page 75).

- Lesson 8: "Facilitate a Building Understandings Discussion. Display slide H. Bring the class together in a Scientists Circle and explain that you will be facilitating a Building Understandings Discussion about the results from the investigation. Remind them that the teacher's role in this type of discussion is to ask students to justify their choices, prompt them for evidence, and ask other groups to either agree or propose alternatives to what is presented. Students should not be surprised or deterred by follow-up questions because we are learning from different ideas. Ask a few groups to share their representations and their claims from the investigation. Use your discussion to compare representations and come to an agreement on the interpretation of the investigation results" (Teacher Edition, page 180).

- The teacher facilitates a "Consensus Discussion" in Lessons 1, 6, 7, and 9. Examples of strategies and teacher guidance for this type of discussion include:
  - Lesson 6: "STRATEGIES FOR THIS CONSENSUS DISCUSSION A Consensus Discussion is different from other kinds of discussions because the purpose of the discussion is to converge on one or more ideas that the whole class agrees upon. In this discussion, your classroom community is pressing toward a common (class-level) explanation of how zombie fires can burn under ice and release so much carbon. During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Helpful prompts include: What ideas are we in agreement about? Would anyone have represented this idea in a different way? Who feels like their idea is not quite represented here? Are there still places where we disagree? Can we clarify these? What evidence do we have to support ____?" (Teacher Edition, pages 139–140).
  - Lesson 9: "While facilitating this discussion, solicit ideas from students that build on other students' ideas by prompting the class with 'Do we all agree with that?' or 'How are these explanations similar? How are they different?' Invite support and critique by asking 'Who has ideas not represented here?' or 'Are there still places we disagree?' Let the class struggle with ways to interpret the model. This is not an easy thing to do and it is a great opportunity for the class to work together to build on the ideas brought forth during the discussion" (Teacher Edition, pages 201–202).
- Students gather in Scientists Circles, which allow for whole group discussion. Scientists Circles are included in Lessons 1, 6, 7, 8, and 9. Some examples of teacher guidance is provided below:
  - Lesson 1: "Your students may be familiar with the Scientists Circle from a previous unit. You will form a Scientists Circle in this lesson and many future lessons. Setting up the community agreements and logistics for forming, equitably participating in, and breaking down that space is important to do now if this is your first time forming such a space. Having students sit in a circle so they can see and face one another can help build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where they need to go next will be an important routine to help students take on greater agency in steering the direction of their learning. This circle will also help students build a sense of pride in their work. You may want to inform students that professional scientists collaborate with one another to brainstorm, discuss, and review their work also" (Teacher Edition, page 46).

  - Lesson 6: "Develop a class consensus model. Display slide I. Ask students to gather in a Scientists Circle. Have students bring their science notebooks and their completed Gotta-Have-It Checklists. Say, What components from our Gotta-Have-It Checklists do we need in our model to explain how zombie fires burn under ice, releasing so much carbon dioxide? As students share their ideas, write a component on a sticky note and add it to the poster. Then follow the same routine with interactions and mechanisms for each component" (Teacher Edition, page 140).
  - Lesson 6: "Develop a class consensus poster. Have students bring their models, notebooks, and pencils to join a Scientists Circle. Display slide V. Say, Let's share what we learned from these case studies and try to agree on a list of conditions that make carbon sinks vulnerable to burning. As students share their ideas, begin to create a list on poster paper titled: What makes a carbon sink more likely to burn?" (Teacher Edition, page 134).
  - Lesson 7: "Display slide V. Say, Let's share what we figured out from these case studies and try to agree on a list of conditions that make carbon sinks more likely to burn. Start by asking each group to briefly describe their carbon sink and the situation that makes it more likely to burn. Then ask students, especially those who 'strayed' during the peer review to discuss some of the similarities they see between case studies that will help the class develop a list of conditions that make a carbon sink likely to burn. As students share their ideas, begin to create a list on chart paper titled: What makes a carbon sink more likely to burn? Use Making Sense Key and Sample Models as guides during the discussion" (Teacher Edition, page 164).
- Opportunities to provide and respond to peer feedback are built into Lessons 5, 7 and 11. Evidence includes:
  - Lesson 5: "Engage in peer feedback. Display slide H. Once every student has a draft of their plan, share Peer Feedback Protocol with them and give them time to review another classmate's investigation plan. Each student should review a peer's feedback and consider revisions to bring to the whole-class discussion" (Teacher Edition, page 119).
  - Lesson 7: "Review the feedback document. Display slide R. Distribute Peer Feedback Guidelines to each student. Say, Use Peer Feedback Guidelines to help you give and receive feedback from your peers as you circulate the room. As you share, ask questions and provide feedback that helps the group to focus on the flow of energy in the system, what makes it a carbon sink, and what conditions make it likely to burn" (Teacher Edition, page 162).
  - Lesson 11: Students share their design solution with peers. They then refine their solutions to strengthen them after peer feedback. "Facilitate a peer review. Display slide R. Prompt students to think about what their next steps are now that they have created a solution" (Teacher Edition, page 251).
- Opportunities for students to revise artifacts of their thinking based on teacher feedback occur in the following lessons:
  - Lesson 3: Rubric 2: Explanation Feedback Guidance: The rubric includes example responses for what foundational pieces, linked understanding, and organized understanding looks like in the explanation. Teacher feedback to provide to students is included for each level of student response, and opportunities to revise their model are offered to students with foundational pieces and linked understanding. "Feedback: *Linking:* Revisit the class model of the yeast system and ask students to consider how the flow of matter and energy changed at different temperatures. Support students in

seeing how the yeast system can be a model of the peat/permafrost system. Ask students to revise their models after review. *Organizing: Review how decomposition* rates affect the flow of matter and energy in both the banana and yeast system models. Ask students what other condition slows down the rate of decomposition. Support students in seeing how both investigations are models of the peat/permafrost system. Ask students to revise their models after review" (Teacher Edition, page 302).

- Lesson 6: Rubric: Zombie Fire Explanation Feedback Guidance: A category "Suggestions for Instruction" on the rubric suggests that teachers ask students to revise their explanations after review if they had a "Linking" level of understanding, which is the lowest category on the rubric. For students with a level of "Organizing" understanding, teachers are instructed to have students rewrite their explanations after a class discussion and review of past investigations (Teacher Edition, page 323).

Suggestions for Improvement
Consider adding the Progress Tracker key to the Teacher Edition so that teachers can easily access it.

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 the materials state the prior knowledge expected for learning and each lesson contains information about the learning progression. Discussion of progression for each dimension is included. The most in-depth supports and discussion of learning progressions focus on the DCI progressions. The materials include guidance for the teacher to support the development of the SEP and CCC elements, however the stated prior knowledge for SEPs and CCC elements is not as detailed as the prior knowledge expectations outlined for the DCIs.

In the front matter of the unit there are sections that display prior learning and how it will be built upon in the unit. However, while the materials specifically state what DCIs students developed in middle school, the same detail is not provided for CCCs and SEPs (Teacher Edition, page 20). The unit overview materials don't elaborate on which elements of the focal CCCs and SEPs are being built on from previous units in the same detail as with the DCIs. Related evidence include:

- The "What elements of the NGSS three dimensions are developed in this unit?" section (Teacher Edition, page 13) states the SEPs and CCCs that are intentionally developed in the unit and how.

- The "How does the unit build three-dimensional progressions across the course and the program?" section provides general titles of SEPs and CCCs labeled as progressions across the biology, chemistry, and physics courses (Teacher Edition, pages 17–18). Specific elements are not stated for these.
- The "What are some common ideas that students might have?" section include portions of prior learning that students may have (Teacher Edition, page 18).
- The "What ideas should my students know from earlier grades or units?" section highlights DCIs from the course and middle school (Teacher Edition, page 20).

The "Where Are We Going" and "Where Are We Not Going" sections provide clarification on how DCIs, SEPs, and CCCs are built over time:

- Lesson 1: "This lesson builds a foundation for the rest of the unit using elementary and middle school grade band ideas related to energy and matter. ideas are established quickly using high school level practices and crosscutting concepts. Students will formally revisit, investigate, and collect evidence for tracking energy and how matter flows into, out of, and within systems to help understand their system's behavior, beginning in Lesson 2. Because this is the first lesson in a new unit, the goal is not to establish any ideas associated with the relevant DCIs, but rather to elicit student ideas related to that DCI. The DCI elements that students will be thinking about in this lesson include: LS1.C.3: As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. ESS3.D.3: Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate: Students use elements of the science practices of Asking Questions and defining problems, developing and using models, and obtaining, evaluating and communicating information to make initial sense of what is happening in the zombie fire system as permafrost thaws and peat burns. Students use elements of the crosscutting concepts cause and effect, systems and system models, and energy and matter as they begin to interact with the unit phenomenon. Students will encounter several terms that are included in previous grade bands in the NGSS performance expectations in this lesson. These include components, interactions, matter, energy, systems, and scale" (Teacher Edition, page 33).
- Lesson 2: "Students use the science practice planning and carrying out investigations. In middle school, students should have had experience evaluating the accuracy of various methods for collecting data. These methods may have been selected by the teacher. Here, they develop the use of this practice by participating in the process of selecting the appropriate tools themselves. They also use this practice in a new way as they consider the ethical implications of their investigation plan. Students use the crosscutting concept energy and matter as they identify how energy and matter flow as fuel burns. They build on the middle school practice as they track the flow of energy and matter together driven by burning within the fuel system and the zombie fire system" (Teacher Edition, page 63).
- Lesson 4: "They develop the disciplinary core idea HS-PS3.D: The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis by building on ideas they should have from middle school such as: The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. MS PS.3D and Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. MS LS1.C Students build on the middle school use the practice of constructing explanations, where they

should have explained relationships between variables, as they make claims about the relationship between solar radiation (independent) and photosynthesis (dependent) in the zombie fire system. Students continue to develop their use of the crosscutting concept energy and matter and use the 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 as they have in previous lessons in this unit" (Teacher Edition page 102).

- Lesson 8: "In this lesson, students build an understanding of DCI: HS-ESS2.D.3: Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. In previous lessons, students see that carbon sinks around the world are burning in wildfires but have not figured out the impact of all of that carbon being released into the environment. This lesson builds on students' past engagement with 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) related to carbon dioxide emissions from burning fossil fuels as a cause of climate change, including more frequent droughts. In addition to what they figured out from prior lessons, students should already understand MS-ESS2.D.1: Weather and Climate Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. This lesson builds on concepts built in middle school OpenSciEd Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit) that explains why precipitation and drought occur. It also deepens the understandings students developed in middle school about MS-ESS3.D: Global Climate Change Human activities, such as the release of greenhouse gases from burning fossil fuels, are significant factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. This lesson builds on elements of science practice planning and carrying out investigations throughout the unit. In Lesson 3, students investigated the relationship between oxygen and temperature and their effect on decomposition to understand how so much peat was in the Arctic. In Lesson 5, students began developing directional hypotheses as they investigated the relationship between varying amounts of light energy and the flow of matter and energy. In this lesson, students are developing a directional hypothesis to predict the relationship between carbon dioxide and temperature as they investigate the consequences of so many large carbon sinks burning globally due to human activity and increasing global temperatures. Students use elements of the crosscutting concept of cause and effect. This lesson builds on previous engagement with cause and effect from Lesson 1, when they began to explore how zombie fires lead to changes in the biosphere and atmosphere. In this lesson, they see that the increase in C0 causes a rise in temperature in a closed system and begin to wonder if this closed system relates to emissions from wildfires and Earth" (Teacher Edition, page 173).
- Lesson 9: "Students continue to develop and use the science practice: Developing and Using Models as well as the focal Crosscutting Concepts Energy and Matter and Systems and System models. This lesson builds toward a consensus model that combines an understanding of photosynthesis and cellular respiration, built in Lesson 6, with the ecosystem models of carbon and energy cycling created in Lesson 7. It adds global scale impacts of burning carbon sinks. Connecting the global scale to previous models introduces the dynamic feedback effects in this complex system. This model is revised over multiple days over the course of the unit, which allows students to spend time developing and using their models. This model also involves

students explaining the matter and energy flow within and between Earth's systems as a whole but also within and between individual subsystems, the hydrosphere, atmosphere, geosphere, and biosphere. The quantitative addition in this model will inform the proportional model of energy moving through a food web students will create in lesson 10. Students should already know from the middle school CCC Systems and System Models elements that: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. In this lesson students link multiple domains through cross cutting concepts, when they build the Gotta-Have-It Checklist for the model, by using energy and matter to explain the interactions and mechanisms that cycle carbon. Then, as the class builds their consensus model, they use the Crosscutting Concept: Stability and Change to understand the problems that arise from positive feedback systems in the model. While this crosscutting concept is not assessed individually here, it is used as a thinking lens to help support the cycling nature of both ESS and LS DCIs" (Teacher Edition, page 189).

There is guidance in the margins and under "Additional Guidance" sections for teachers that discuss the progressions of the focal CCCs and SEPs throughout the unit. Evidence includes:

- Lesson 1: There is guidance for supporting students in developing and using **Systems and System Models**. "In high school, students build on their middle school use of systems and system models where they modeled energy flows in systems. Here, they should begin to identify the boundaries of the zombie fire system, what is included and what is beyond it. This will lead them to begin to consider what other systems surround the zombie fire system and how those systems interact" (Teacher Edition, page 44).
- Lesson 1: Since models are used to explain a range of phenomena, students will refer back to this list of related phenomena throughout the unit to help them generalize the model(s) they develop and predict interactions in other systems. As students suggest ideas, press them to explain how they are related. This will help students expand their thinking beyond the individual components to the interactions and mechanisms that will be explained by their models (Teacher Edition, page 43). This sidebar is a tool to support teachers in growing students' thinking about this SEP, however, it would help to include the element of the SEP that is being developed and used.
- Lesson 2: "In the NGSS, matter and energy are introduced early in the K-2 and 3-5 elementary school grade bands. From their experiences in school and their everyday lives, students will likely be familiar with these terms. However, it is important for the class to have a common understanding of their definitions as they progress through the unit. Encourage students to describe matter by classifying the observable and unobservable parts of materials they observe and energy by considering moving objects at both the macro and microscopic scales" (Teacher Edition, page 65).
- Lesson 3: There is verbiage to help students who have gaps in the practice of planning and carrying out investigations through a banana investigation. There is verbiage to differentiate the high school element from the middle school element. "An important element of planning and conducting an investigation at the high school level is to do so safely and in an ethical manner, including considerations of the personal, societal, and environmental impacts. Establishing safe and ethical scientific investigations as an explicit principle and referring to it often will help students start to use it as a default lens to evaluate what they or others propose to do before doing it, such as when they outline or critique the protocols or proposed/alternate procedures

for an investigation. Help students consider how model organisms, like yeast, can be used in service of ethical decisions in scientific investigations" (Teacher Edition, page 87).

- Lesson 3: The sidebar describes the experience students would have had with identifying independent and dependent variables in middle school and how to build towards the grade-appropriate element of cause and effect (Teacher Edition, page 90).
- Lesson 3: An additional sidebar describes students' experience with controls (Teacher Edition, page 90).
- Lesson 5: There is support planning and carrying out investigations which includes what prior learning students have regarding the practice and how it should be built upon. "Students should have had an opportunity to frame hypotheses as they developed SEP 1 asking questions and defining problems in middle school. In high school, students build on framing hypotheses from scientific principles and observations to specify expected relationships between independent and dependent variables when planning and carrying out investigations" (Teacher Edition, page 116).

Suggestions for Improvement

- Consider further identifying the learning progression for the CCCs and SEPs, in a level of detail similar to that given to the DCI so teachers can see how all elements are used throughout the unit.
- Consider including the targeted SEP or CCC element in the sidebar call outs.

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	Adequate (None, Inadequate, Adequate, Extensive)

The reviewers found adequate evidence that the materials use scientifically accurate and grade-appropriate scientific information. The vast majority of all science ideas and representations included in the materials are accurate. The materials do acknowledge that student ideas and definitions in their Personal Glossaries will evolve as they learn the material. However, there is potential for students to create a misconception regarding glucose versus sucrose.

Texts used in the unit have references listed. Some examples include:

- "Additional Guidance" sections throughout the Teacher Edition provide background information for the teacher that is largely scientifically accurate. There is guidance for the teacher that table sugar is actually sucrose. "Table sugar is actually sucrose, made from glucose and fructose. However, for the purposes of this lesson we are equating sugar and glucose. High interest students may be motivated to know more about the structure of sucrose and its relationship to glucose" (Teacher Edition, page 89). Slide G shows a bag of sugar and an inset image of the molecule glucose. Students may create a misconception when table sugar is equated and referred to as glucose when they review the image on the slide from Lesson 2 that has glucose on it. Although the materials suggest that "high interest students" (Teacher Edition, page 98) may be motivated to learn about the relationship between sucrose and glucose, this will not resolve the potential misconception for the rest of the students.

- Throughout the unit, students read scientific texts. These articles are written at a grade-appropriate level and are scientifically accurate. Some examples include:
  - Lesson 1: The inquiry slides have citations.
  - Lesson 2: The "Peat, Permafrost, Carbon" reading has six sources from NASA, International Peatlands Society, and others.
  - Lesson 4: The Geologic Time reading contains citations and images from reputable scientific organizations.
  - Lesson 10: The case studies have citations.
- The materials utilize video and images from reputable scientific organizations.
- There are reputable sources provided for adult-level learning for the teacher (Teacher Edition, pages 22–23).
- It is stated that the Personal Glossaries of students will evolve and change as students learn more and progress through the unit. "Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a personal glossary at the back of their notebooks. These 'definitions we codevelop' should be recorded using the students' own words whenever possible. On the other hand, 'definitions we encounter' are 'given' to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes definitions we encounter are helpful just in that lesson and need not be recorded in students' personal glossaries. However, if a word we encounter will be frequently referred to throughout the unit, it should be added" (Teacher Edition, page 25).

Suggestions for Improvement

Consider a clearer note for teachers to differentiate sucrose and glucose to avoid the creation of a misconception for students regarding table sugar, even if it is stating the "Additional Guidance" on page 89 aloud to all students. "Table sugar is actually sucrose, made from glucose and fructose. However, for the purposes of this lesson we are equating sugar and glucose."

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	Extensive (None, Inadequate, Adequate, Extensive).

The reviewers found extensive evidence that the materials provide guidance for teachers to support differentiated instruction because the materials explicitly clarify how they anticipate the needs of various student groups, include guidance at some critical steps in the learning sequence, and include strategies for multilingual learners, learners who read below grade level, and struggling students. The materials reference Universal Design for Learning (UDL) principles in sidebars and how these strategies support specific groups of students including students above or below grade level proficiency, students learning English, and students with visual differences. The sidebar materials support students in using the type of representation that works best for them throughout the learning process. There are extension opportunities, but they are not always fully developed to help students push their thinking in each of the three dimensions.

There are supportive ways to access instruction for different student groups as well as extra support for students who are struggling to meet the targeted expectations. Related evidence include:

- Lesson 7: Answer Key: The Making Sense Key instructs teachers to actively look for ways students can represent their ideas in different ways and states, “opportunity to communicate to your students that different ways of representing our thinking are valuable” (Teacher Edition, page 331).
- Supports are provided for students who may be struggling. For example:
  - Lesson 6: “If students are stuck, and you need to get them to think more deeply about the processes happening or mechanisms responsible, consider walking through the lessons in chronological order” (Teacher Edition, page 141).
  - Lesson 6: “If students need further support, use the sentence starters such as those found on Peat/Permafrost Scaffolded Explanation” (Teacher Edition, page 144).
- Supports are provided for emerging multilingual learners in Lessons 1, 3, 4, 6, 7, 9, and 11. For example:
  - Lesson 11: “Supporting emergent multilinguals: Students should be encouraged to record their ideas using linguistic (e.g., written words) and nonlinguistic modes (e.g., drawings, tables, graphs). This is especially important for emerging multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of how fire management systems work” (Teacher Edition, page 251).

- Support is provided for differentiation based on interest or difficulty level. For example:
    - Lesson 7: The case studies can be differentiated and there is guidance to help the teacher with differentiation strategies. "The case studies are written at similar reading levels and contain equally rigorous scientific information. However, they vary in length and complexity of graphical data and historical ideas. You may wish to allow students to select readings based on interest before dividing them into groups. At your discretion, you can assign students to intentional, mixed-ability reading groups, with the students who need more reading support along with students who do not need the extra support" (Teacher Edition, page 157). One of the case studies also includes a video.
    - Lesson 8: "ATTENDING TO EQUITY Universal design for learning: Providing students with the opportunity to choose the level of perceived challenge can support engagement and help develop self-determination and pride in accomplishment and increase the degree to which they feel connected to their learning. You may wish to allow students to select readings based on interest before dividing them into groups. These readings have also intentionally been written to have different levels of difficulty" (Teacher Edition, page 172).
- Opportunities are provided for students who have high interest and want to learn more. For example:
    - Lesson 3: There is an extension opportunity as students work through the revision of the class model. "Challenge students who have already met the standard to balance the flow of matter from start to finish in cellular respiration. Let them know that glucose is C H O and ask them to determine how many oxygen, carbon dioxide and water molecules must be part of the process so that all matter is conserved" (Teacher Edition, page 97). There are no follow up questions or guidance on how to connect this information to the DCIs, CCCs, or SEPs.
    - Lesson 8: "Extension activity: By this time in the unit, students may be inquiring about how they can make different choices that could reduce the amount of carbon that they produce with their lifestyle (carbon footprint) and inspire student agency. Share EnergyStar.gov's Carbon Footprint by resources for students to collect baseline data to measure the impact of their decision-making (with their community members) on the flow of carbon in their area. https://www.energystar.gov/ia/products/globalwarming/downloads/GoGreen_Activities%20508 _compliant_small.pdf Digital version that shares facts and figures, assesses feelings around the results with suggestions on how to relate those feelings to action, opportunities to explore your data, and potential solutions to reduce the number of Earths that are necessary for your lifestyle/personal Overshoot Day: https://www.footprintcalculator.org/home/en" (Teacher Edition, page 182).
    - Lesson 9: "If students want to better understand the relationship between photosynthesis and global atmospheric carbon dioxide levels, ask them to look at the patterns found in the data from the Mauna Loa Observatory. This shows that plants can cause seasonal fluctuations on a large scale. Play the animation at https://gml.noaa.gov/ccgg/trends/history.html (from the beginning until 1:36) or look at the static image of the data at https://gml.noaa.gov/ccgg/trends/" (Teacher Edition, page 190).
- Supports are provided for students who are color blind or have other visual differences in Lessons 1, 6, and 9. For example:

- Lesson 6: "Universal Design for Learning: Using different representations such as a smiley and heart instead of just colors allows for increased access to the task, especially for students with vision differences" (Teacher Edition, page 135).
- Lesson 9: "Universal Design for Learning: Use representations like color coding and/or letter or number coding to foreground parts of the model. Create a key to track what colors, symbols, or letter or number codes represent different parts of the system. While color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color blind. If color coding is used, consider a color palette that uses orange, blue, black, or dark brown" (Teacher Edition, page 202).

Suggestions for Improvement

- Consider building in differentiation strategies (e.g., format and product) for the summative assessment tasks.
- Consider having explicit verbiage and/or specific questioning strategies for students during the extensions to better show how "extension" or "challenge" opportunities could explicitly connect and build on the SEPs, CCCs, and DCIs so extension opportunities can be more purposeful for students.

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 because guidance and support are provided consistently throughout the unit on how teachers can support students to connect phenomena across lessons, support engagement across lessons, and to link and develop the three dimensions. The materials have specific call-outs to developing and using the SEPs and CCCs and describe the connections between lessons explicitly at the beginning of each lesson, along with a list of what concepts students will figure out. There is also specific guidance to help teachers better understand the science concepts of the unit as well as support the social and emotional needs of the students throughout the unit.

Related evidence includes:

The navigate section of the lessons supports teachers in centering student learning and prompts students to return to figuring out the phenomenon regularly.

- Lesson 2: The navigate section suggests students reflect and share out on questions such as what they figured out about burning zombie fires in the Arctic last class and that next steps are figuring out more about permafrost and how peat can burn under ice (Teacher Edition, page 64).
- Lesson 3: The navigate section helps students link their learning from last time about peat and permafrost towards new questions about peat (Teacher Edition, page 84).
- Lesson 4: The navigate section prompts the teacher to problematize the presence of peat in the Arctic to help students generate questions around why there is so much plant matter in a cold and snowy location (Teacher Edition, page 103).
- Lesson 5: In the Learning Plan for Lesson 5 section, Earth's tilt is reviewed which is a sub-phenomenon that is scaffolding students towards figuring out what led to the peat accumulating in the Arctic and connecting the last lesson to the need for an investigation (Teacher Edition, page 116).
- Lesson 6: As students pause in Lesson 6 to come to consensus around what they know about zombie fires as carbon sinks that are releasing so much carbon dioxide through burning, the three dimensions are clearly linked and in service of figuring out the phenomena — drawing models and communicating ideas with others to explain the concepts (Teacher Edition, page 134).
- Lesson 7: Teachers are prompted to draw out student responses relating to curiosity about investigating other places in the world where fires are happening. This is teeing up the learning in Lesson Set 2 that connects the phenomena in Lesson Set 1 with related sub-phenomena and global connections (Teacher Edition, page 155).
- Lesson 8: Lesson 8 begins to add a forward-thinking lens to the zombie fires phenomena. Here students are figuring out one outcome of what happens to the atmosphere and temperature when so much carbon dioxide is released (Teacher Edition, page 174).
- Lesson 9: Students are supported in linking the CO2-temperature bottle investigation results they carried out in Lesson 8 into the analysis of global temperature trends to help figure out the same sub-phenomena, what is the result of the burning of carbon sinks (Teacher Edition, page 191). What is important in each of these lessons is that when new phenomena are introduced, the materials include prompts for teachers and students that help link each, so they are not being introduced in an unrelated, haphazard manner.
- Lesson 10: This navigate section again centers student responses and questions to figure out the phenomena, how to manage carbon sinks and in this case, learning from people who are doing that (Teacher Edition, page 214).
- Lesson 11: This section includes a strategy to have students share home learning and bring in their own experiences and ideas relating to the phenomena of fire management (Teacher Edition, page 241).
- Lesson 12: Student ideas do not drive this section. This lesson is satisfying the need for a transfer task and demonstration of understanding of the unit key concept.

Other supports include:

- At the beginning of each lesson in the Teacher Edition there is a "Where We Are Going and NOT Going" statement that explains the summary of what the key points of the lesson are for teachers as well as areas they shouldn't go to in that specific lesson.
- The DQB is developed in Lesson 1 and used to brainstorm questions, investigations, and sources of data that could help figure out the phenomenon. Students return to the DQB in Lessons 1, 2, 5, 6, 7, 9 and 11 to add questions or to determine which questions have been answered.

- This unit uses a Progress Tracker where students periodically add updates to their learning and understanding of the unit phenomenon. It is unclear if students use the Progress Tracker to think about their learning in all three dimensions.
- There is guidance to help teachers better understand the science concepts of the unit. "What are recommended adult-level learning resources for the science concepts in this unit?" (Teacher Edition, page 22).
- There is guidance to help with students' emotional needs in the unit (Teacher Edition, pages 24–25).

Suggestions for Improvement

Consider using the Progress Tracker as a way for students to update their learning in all three dimensions. In addition, adding to the Teacher Guide consistent information on what teachers should look for in students' responses on their progress trackers would help teachers anticipate and build upon students emerging ideas and mental models in subsequent lessons.

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.

Rating for Criterion II.G. Scaffolded Differentiation Over Time	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials support teachers in helping students engage in the practices as needed and gradually adjust supports over time because the materials provide guidance for reducing scaffolds for some targeted SEPs so that students become increasingly independent in engaging with the SEP. Some scaffolds are optional in the materials, therefore, not all teachers may provide the optional scaffolding for their students. Additionally, the materials don't provide guidance for where and when to add and remove scaffolds to move students towards mastery and independence of the target SEPs. The materials don't explicitly address how to support all students in building proficiency in all SEPs, especially students with disabilities.

Evidence related to the following SEP element includes:

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

- *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system* (SEP **2.3**).
  - Lesson 1: Students develop an initial model of the zombie fire system and incrementally build the components, interactions, and mechanisms of their revised models in later lessons. Teacher prompts include asking students to identify the components of the zombie fire system, how matter might cycle in it, how energy might flow in it, how the components interact, and what mechanisms might explain what is happening (Teacher Edition, page 44).

- Lesson 6: Small groups develop a model of a different fire system/carbon sink. They come to consensus as a class and are prompted to identify if their own model is missing components, to add them to the model, a possible representation of the model is included for teacher support (Teacher Edition, page 140).
- Lesson 9: Students develop a quantitative model to simulate the flow of carbon and energy through earth's system individually (Teacher Edition, page 196). They then revise their Gotta-Have-It Checklists and engage in a discussion to come to consensus on the model for global fire system based on evidence (Teacher Edition, pages 199–201). Students focused on learning this element in groups early in the unit and in Lesson 9 have the opportunity to apply the earlier learning to an individual scenario. This lesson therefore progresses students' proficiency in using the SEP element.
- Lesson 12: In the Dead Zone Transfer Task, students develop a model of a carbon and oxygen cycle in the Gulf of Mexico (Teacher Edition, page 259).

Students engage with **Planning and Carrying Out Investigations** elements several times in the unit, but the scaffolding doesn't build toward student independence, and they aren't reduced in the unit.

- *Select appropriate tools to collect, record, analyze, and evaluate data* (SEP **3.4**).
    - Lesson 2: In the **Supporting Students in Engaging in Planning and Carrying out Investigations**, teachers are prompted to have students reflect on which method and tool they select for the investigation has differing accuracy and constraints, e.g., carbon dioxide and oxygen probes compared to BTB (Teacher Edition, page 72). This is an authentic example of developing the SEP.
    - Lesson 3: There is an Additional Activity to help students with this element within the lesson. "If you have additional supplies available and/or want to support students in selecting tools to collect data (SEP 3), carbon dioxide probes, flasks or bottles covered with balloons or other methods of capturing carbon dioxide gas, offer students these options here and alter Decomposition Investigation Plan and slide M as needed" (Teacher Edition, page 91). However, because this is an optional activity, not all students may have an opportunity to develop the element through this activity.
    - Lesson 5: The teacher asks questions to help the students consider how the tools selected will be used to collect and record data. "If our independent variable is about the energy from the sun based on Earth's tilt, what can we do in our classroom to simulate that? How can BTB help us measure that change?" (Teacher Edition, page 120). However, scaffolding is not reduced in the SEP throughout the lessons.
- *Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable results* (SEP **3.2**).
    - Lesson 3: Students use an investigation planning tool to plan the decomposition investigation (Teacher Edition, page 90). They are supported in considering this element through teacher-prompted questions like, "How can we decide what temperature the beakers should be?" and "What will help us answer our questions about the zombie fire system?" (Teacher Edition, page 91).
    - Lesson 5: While students carry out their Photosynthesis Investigations, they use the *Photosynthesis Investigation Plan* handout. The teacher is prompted, "Say, This plan incorporates the ideas from your plans yesterday and takes into account the materials and time we have in our classroom. Highlight ideas that individual groups contributed to the class plan" (Teacher Edition, page 121). However, students did not have the

opportunity to create their own investigation plans and were not scaffolded to do this element.

Suggestions for Improvement

- Consider incorporating guidance for teachers for where and when to add or remove scaffolds to move all students towards becoming independent in the use of all targeted SEP elements.
- Consider reducing scaffolding for student use of focal SEP elements throughout the progression of the unit. For example, students could learn and practice an element as a class early on in the unit and progress gradually toward independent use of the SEP element later in the unit.

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 and/or design solutions because student artifacts that require grade-appropriate elements of all three dimensions used together are used to evaluate most targeted learning. However, there are some missed opportunities for monitoring three-dimensional student performances in key moments of making sense of the phenomena, for example, during the investigations in Lessons 2, 5, and 8, and in the modeling development during Lessons 3.

Some evidence of three-dimensional student performance includes:

- Lesson 3: Students construct a written explanation for why there is so much carbon and energy in peat in the peat/permafrost system. In this task, students the use the following elements of the three dimensions:
  - SEP: **Constructing Explanations and Designing Solutions** *Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*
  - DCI: **LS2.B:** Cycles of Matter and Energy Transfer in Ecosystems *Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.*
  - DCI: **LS1.C:** Organization of Matter and Energy Flow in Organisms *As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken, and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.*
  - CCC: **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.*
- Lesson 6: Zombie Fire Explanation: Students construct an explanation of how zombie fires could be burning under ice and releasing carbon dioxide. In this task, students the use the following elements of the three dimensions:
  - SEP: **Constructing Explanations and Designing Solutions** *Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*

- DCI: **LS2.B:** Cycles of Matter and Energy Transfer in Ecosystems *Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.*
- CCC: **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.*

Suggestions for Improvement

- Consider providing students with opportunities for the creation of individual artifacts that use grade-appropriate elements of all three dimensions used together in key moments of sense-making, such as during investigations.
- Consider providing more deliberate opportunities for teachers to observe individual student progress on modeling.

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 because every lesson has multiple opportunities for formative assessment. Multiple formative assessment opportunities are called out utilizing "Assessment Opportunity" boxes and are integrated into the learning sequences. Teacher guidance is provided for "what to do" with respect to student thinking. Formative assessment processes attend to some issues of student equity.

Some examples of formative assessment opportunities include:

- Lesson 1: Students conduct a visual inquiry where they obtain information about cause-and-effect relationships that lead to changes in the atmosphere and biosphere. The materials include explicit support for formative assessment processes while students conduct their visual inquiry. The supports are provided in an Assessment Opportunity box with "What to look for/listen in the moment" and "What to do" sections (Teacher Edition, page 38). There is guidance for what types of questions to ask if students aren't connecting key ideas. The materials suggest modifying instruction if student responses don't resemble the responses on the key by allowing additional time.
- Lesson 2: Students revise their investigation ideas. There is guidance of how to sort student groups to help inform instruction and help students in the next portion of the lesson. "What to look for/listen for in the moment: Evidence of energy and matter flow when burning such as matter in peat recombining to form carbon dioxide and water. (SEP: 3.4; DCI: LS1.C.3; CCC: 5.4) Ideas for tools to collect evidence of the flow of energy and matter when burning fuel samples.

(SEP: 3.4; DCI: LS1.C.3; CCC: 5.4) Note: at this stage students need only to suggest a tool that makes sense e.g., device to measure carbon dioxide. They do not need to name a specific kind of tool. What to do: Following the class discussion, invite students to review their responses and then collect Investigation Planning Workspace. Sort student responses to inform grouping for the Burning Fuels investigation on day 2. Use the following three categories as a guide to sorting student responses: 1. students that demonstrate an understanding of evidence of energy AND matter and have at least one idea for a data collection tool 2. students that demonstrate an understanding of how to collect evidence of energy OR matter with or without an idea for a data collection tool. 3. students that do not yet demonstrate an understanding of what could be considered evidence of energy and matter changes with or without an idea for a data collection tool. On day 2, use the piles to create groups that distribute students from each pile across groups" (Teacher Edition, page 71).

- Lesson 3: Rubric 2 Explanation Feedback Guidance: The rubric includes a Feedback section that suggests what a teacher can do to support students in this learning moment. "Revisit the class model of the yeast system and ask students to consider how the flow of matter and energy changed at different temperatures" (Teacher Edition, page 308).
- Lesson 4: Exit Ticket Key: The key includes "What to do" and "what to look for" sections that provide guidance on using the student responses and adjusting instruction accordingly (Teacher Edition, page 318).
- Lesson 5: Students complete the "Hypothesis Development" activity. There is guidance on how to inform instruction based on student responses. "What to look for/listen for in the moment: Directional hypotheses (SEP: 3.5) that identify: Solar radiation/light energy as the independent variable (SEP: 3.5; DCI: LS1.C.1; CCC: 5.2) Photosynthesis and carbon stored in plants as the dependent variable (SEP: 3.5; DCI: LS1.C.1; CCC: 5.2) What to do: Collect Hypothesis Development from each student. Check to make sure students correctly identify the variables and the direction of the relationship. For students who need support with either variables or relationships, check in with them while they are working individually and in small groups on investigation planning to support their thinking. If students do not correctly identify the dependent and independent variables, point them to the terms cause and effect to help them see the relationship. Use a prompt such as which variable causes a change in the other? If students do not choose the correct direction of the relationship, ask them to explain the relationship in pictures or words with prompts such as, How is energy flowing in this system? What happens when there is a change in the amount of energy available. Return Hypothesis Development while they work on investigation planning so they can recall their direction hypothesis" (Teacher Edition, page 116).
- Lesson 6: Rubric: Zombie Fire Explanation Feedback Guidance: A category "Suggestions for Instruction" on the rubric suggests that teachers ask students to revise their explanations after review if they had a "Linking" level of understanding, which is the lowest category on the rubric. For students with a level of "Organizing" understanding, teachers are instructed to have students rewrite their explanations after a class discussion and review of past investigations (Teacher Edition, page 323).
- Lesson 9: Exit Ticket Key: The key includes "What to do" and "what to look for" sections that provide guidance on using the student responses and adjusting instruction accordingly (Teacher Edition, page 45).
- Lesson 10: Students in small groups revise the consensus model from earlier lessons. "What to look for/listen for in the moment: Visit groups and review how students are editing the Lesson 7 model with what they figured out for their case study. Look and listen for scientific reasoning that supports an explanation (SEP: 6.4) for each case study: Wisconsin Case Study (Case 1) and

Cultural Burning Case Study (Case 3): Prescribed burning reduces the amount of carbon and energy in the carbon sink available to burn. (DCI: LS2.B.2; CCC 5.3) Animal Grazer Case Study (Case 2): Adding grazers to the model reduces the amount of carbon and energy available to burn because some of it moves from plants into animals. (DCI: LS2.B.2; CCC 5.3) Trees Case Study (Case 4): Planting trees shifts the carbon and energy balance in ecosystems by sequestering more from the atmosphere into the trees. (DCI: LS2.B.2; CCC: 5.3) Students will edit their Lesson 9 consensus models differently depending on which case study they are reading. Assess accordingly. What to do: Circulate around the room to formatively assess students' revisions. Bring your class roster and mark off when you hear a student correctly apply scientific reasoning to link evidence from their case study. Responses to Case Studies is a guide summarizing the main points of each case. Use the following prompts with groups: What is happening to the carbon and energy in this ecosystem? How do you know? Wisconsin Case Study (Case 1) and Cultural Burning Case Study (Case 3): How could setting a fire purposely help manage wildfires? What is and is not burning in this method compared to a wildfire? Animal Grazer Case Study (Case 2): What are the cattle eating? Is what the cattle eats the same material that burns during a wildfire? Why are cattle and other grazers important to grassland ecosystems? Trees Case Study (Case 4): Why does planting trees create more resilient forests? What are the impacts to other living things in forests when areas are readily deforested? If students have questions or comments related to power and historicity in the case study, encourage them to record their ideas in their notebook for discussion on Day 3. Encourage questions about quantifying how much must be burned or eaten to have a positive impact to lead into the discussion on day 2 of the lesson" (Teacher Edition, page 217)

There is specific guidance for a range of student responses (foundational pieces, linked understanding, and organized understanding) and how to respond to them on some formative opportunities through "feedback/ideas for instruction" for each level of response. This allows for a deeper evaluation of student learning. This guidance is located within the Lesson-Specific Teacher Materials towards the end of the Teacher Guide. They include:

- Lesson 3: Explanation Feedback Guidance (Teacher Edition, pages 301–303)
- Lesson 6: Zombie Fire Explanation Feedback Guidance (Teacher Edition, pages 321–324)
- Lesson 12: Dead Zone Key (Teacher Edition, pages 357–370).

Other evidence includes:

- Assessment System Overview: A summary of opportunities for formative assessments is provided for each lesson. Teachers are given guidance about when to use the assessment and what to look for in student responses (Teacher Edition, pages 266–278).
- Each lesson provides at least one formative assessment opportunity connected to a three-dimensional LLPE where guidance is provided on what to look for and what to do. These provide teacher guidance on how to modify instruction based on student responses.

Suggestions for Improvement

Consider additional guidance such as rubrics or teacher materials on how to modify instruction based on multiple possible levels of student responses or student proficiency, similarly to the level of detail that has been provided for assessments in Lessons 3, 6, and 12.

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 materials include aligned rubrics and scoring guidelines that help the teacher interpret student performance for all three dimensions because general scoring guidance is provided for key assessments. The scoring guides include exemplary student responses. However, a range of student responses are sparingly provided — not allowing for specific, individualized feedback based on the level of proficiency the response is showing.

Related evidence includes:

- Lesson 3: Rubric 1: The Investigation Plan Checklist includes a Feedback column that corresponds to a checklist for items the Investigation Plan needs to include. The Feedback column says, “Feedback (If these items are not present, what could you tell the learner to support them?)” (Teacher Edition, page 301). However, the column is blank. The reviewer assume that it is intended as a tool for teachers to come up with their own feedback to students based on their performance.
- Lesson 3: Rubric 2: The rubric to support teachers in providing feedback is structured to call out the three dimensions and how each dimension fits into the explanation (Teacher Edition, page 301).
- Lesson 3: Answer Key: While the key doesn’t include a range of sample student responses, it provides exemplary responses (Teacher Edition, page 305).
- Lesson 4: Exit Ticket Key: The key includes “What to do” and “what to look for” sections that provide guidance on using the student responses and adjusting instruction accordingly. For example, Question 5 is “When choosing a claim, how did you determine which variable was the dependent and which was the independent?” and below that instructions for teachers are, “What to look for in response: Note: These could be different for each student. Students should identify solar radiation as the independent and the amount of photosynthesis as the dependent variable. What to do: Encourage student to think about which variable causes a change in the other variable (effect)” (Teacher Edition, page 313). The rubric color codes the portion of the question and feedback that corresponds to one of elements of the three dimensions (Teacher Edition, pages 309–313). A summary chart at the top of the rubric marks an X in a table for which element of which dimension is addressed per question on the Exit Ticket (Teacher Edition, page 309).
- Lesson 6: Rubric Zombie Fire Explanation Feedback Guidance: The Zombie Fire Explanation Feedback Guidance (Teacher Edition, page 321) is set up explicitly to track three-dimensional elements and sample responses at each level (foundational pieces, linked understanding, organized understanding). There are suggestions for what feedback to provide and how to modify instruction based on the level and type of responses students provide.

- Lesson 7: Sample Models: One possible example of a model for each case study is provided (Teacher Edition, pages 325–329).
- Lesson 7: Making Sense Key: Ideal student responses are marked in purple (Teacher Edition, pages 331–332). There is not a range of student responses at differing levels of proficiency.
- Lesson 8: Sample CO2 Temperature Investigation Response: Ideal student responses are marked in purple (Teacher Edition, pages 333–335). There is not a range of student responses at differing levels of proficiency.
- Lesson 9: Electronic Answer Key: This is a multiple-choice key that shows the correct response and “what to look for in response” with “what to do” (Teacher Edition, pages 337–345). There is not specific and targeted guidance for why students may have selected a wrong response and what misconception or incomplete understanding that answer means.
- Lesson 9: Global Carbon and Energy Flow Key: Ideal student responses are marked in purple (Teacher Edition, pages 347–348). There is not a range of student responses at differing levels of proficiency.
- Lesson 9: Responses to Case Studies: Ideal student responses are marked in purple (Teacher Edition, pages 349–350). There is not a range of student responses at differing levels of proficiency.
- Lesson 9: Electronic Exit Ticket: The rubric to support teachers in providing explanation feedback incorporates the assessment targets — the three dimensions and how each dimension fits into the explanation (Teacher Edition, page 343).
- Lesson 11: Fire Solutions Sample: Ideal student responses are marked in purple (Teacher Edition, pages 353–356). There is not a range of student responses at differing levels of proficiency.
- Lesson 12: Transfer Task: The rubric includes a chart of the assessment targets that identifies elements of the CCCs, DCIs, and SEPs being assessed (Teacher Edition, page 363).

There are opportunities for students to monitor their own learning and progress and interpret their own performance. Some examples include:

- Lesson 1: “Check in with students as they revise their models and construct the class consensus model to track their individual understanding” (Teacher Edition, page 45).
- Lesson 6: “...Students share ideas to reach a consensus and revised model, it is important that they think about how to treat each other with respect while moving our understanding forward. This is a good place to emphasize that respect does not mean always agreeing, and challenging each other’s ideas needs to happen respectfully. This can look like disagreeing with ideas, not people, and being willing to listen carefully to our classmates and change our thinking about a problem” (Teacher Edition, page 135).
- The progress tracker is an informal way for students to see their progress and thinking.

Suggestions for Improvement

- Consider providing guidance for reasons why students might select the wrong multiple-choice question and how to respond to each so students can get more explicit feedback.
- Consider putting “what to do/how to inform instruction” into all assessment keys so it is explicitly clear to teachers how to provide targeted feedback to students as they are using the keys and rubrics.
- Consider creating scoring guidance as detailed and explicit as what is provided for assessments in Lessons 3, 6, and 12.

III.D. UNBIASED TASK/ITEMS

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

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

The reviewers found extensive evidence that the materials assess student proficiency using accessible and unbiased methods, vocabulary, representations, and examples because texts are grade-appropriate, there are some scaffolds in the materials for cultural bias in the phenomenon, and there are limited opportunities for choice of modality. There is student choice in how they show their proficiency in multiple lessons. The vocabulary, readings, and resources are grade appropriate.

Related evidence include:

- The text and vocabulary/modes of communication are grade level appropriate and text in tasks is frequently accompanied by other methods. Evidence includes:
  - Lesson 6: The case studies "have also intentionally been written to have different levels of difficulty" perhaps allowing students to choose. (Teacher Edition, page 134).
- Bias/supports:
  - Supports are provided for students who may be struggling. For example:
    - Lesson 1: There is a note about limitations of the phenomena. "While students may not feel geographically connected to the Arctic there are peat fires happening all over the earth, in many regions. Additionally, this is a chance to highlight other knowledge systems, cultural connections to fire, and connections to changes in places, lands, and waters. For examples of recent fire stories shared by students, please see Fire Stories. In addition, if your students have trouble connecting with fires impacting their communities you could use Fire Stories to share stories from other high school students." (Teacher Edition, page 42).
    - Lesson 2: In the burning lab, it is encouraged to use fuel samples that are local.
  - There are supports for onboarding students to zombie fires and the related phenomena. Some examples include:
    - Lesson 1: The inquiry activity has photos and other pictorial representations.
    - Lesson 7: The case studies have pictures.
    - Lesson 12: The transfer task about dead zones has appropriate resources to help students understand the task even if they do not have a familiarity with the ocean.
  - Texts are at grade level and incorporate information related to the DCI elements for high school.
  - Lesson 6: "If students are stuck, and you need to get them to think more deeply about the processes happening or mechanisms responsible, consider walking through the lessons in chronological order." (Teacher Edition, page 141).

- Lesson 6: "If students need further support, use the sentence starters such as those found on Peat/Permafrost Scaffolded Explanation." (Teacher Edition, page 144).
- Supports are provided for emerging multilingual learners in Lessons 1, 3, 4, 6, 7, 9, and 11.

- Supports are provided for differentiation. For example:
  - Lesson 8: "ATTENDING TO EQUITY Universal design for learning: Providing students with the opportunity to choose the level of perceived challenge can support engagement and help develop self-determination and pride in accomplishment and increase the degree to which they feel connected to their learning. You may wish to allow students to select readings based on interest before dividing them into groups. These readings have also intentionally been written to have different levels of difficulty" (Teacher Edition, page 172).

There is variety in the modalities expected for student responses. For example:

- Lesson 6: On the assessment regarding zombie fires, students have the option to write or draw (model) their explanation.
- Lesson 9: "3. Write and/or draw a brief story in words and/or images from your carbon atom's point of view that describes the journey it just took through the earth's spheres. Make sure to include the system, what happened, and where it went next. Choose specific members of the system (for example: say zebra, not herbivore). Be creative!" (Global Carbon and Energy Flow Simulation).
- Lesson 11: "Now that we have designed our final fire management solutions, we get to decide how we are going to share them. Offer student groups a choice between products such as a poster, a video, a PowerPoint/Google Slides presentation, sample podcast, etc., based on what can be offered in your classroom/school context. Encourage students to be creative by including at least 2 different formats: graphic, textual, visual, etc., and to choose the product that best fits their intended message and audience" (Teacher Edition, page 252).
- Lesson 12: Student Handout Dead Zone Transfer Task Question 10: "Create a model below using words and/or drawings…Your model can be explained visually, through illustrations with labels, explained in writing, explained through speaking. Choose your preference, and let your teacher know" (Dead Zone Transfer Task, page 9). In this summative task, students are given a meaningful choice to convey the information they learned throughout the lessons.

Suggestions for Improvement

None

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 outlines a system of assessments which includes pre-, formative, and summative assessments that engage students in sense-making of phenomena and is mostly aligned with three-dimensional learning goals.

Guidance is provided for teachers to see how the provided assessments work together to form a coherent assessment system. Related evidence includes:

- The "Assessment System Overview" chart details for teachers what documents correspond to each lesson assessment and scoring guidance and the purpose of assessment (Teacher Edition, pages 266–270).
- Lesson-by-Lesson Assessment Opportunities: This document includes what LLPEs are in each lesson as well as assessment guidance (Teacher Edition, pages 270–278).
- Within the lessons there are "What to look/listen for in the moment" during assessment opportunities to help the teacher better assess intended student learning. These are linked to the three dimensions.

All four types of assessments are included.

- Pre-Assessment
  - Lesson 1: The initial model and DQB can be considered pre-assessment. "Circulate around the room as students develop their initial models. Use these initial models as a pre-assessment opportunity to check in on students' use of systems and system modeling as well as energy and matter. Make note of whether or not individual students identify the peat/permafrost and carbon dioxide as both matter and energy that flow from one form to another via fire. Also note whether student models include any matter and energy flowing out of the zombie fire system. Walk around the room with a clipboard and roster, check off who has matter and energy arrows (or the other agreed upon representation) on their models., when you come back check later in the unit and you can see who has made progress" (Teacher Edition, page 45).
  - Lesson 1: "The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions and to post to the board" (Teacher Edition, page 266).
- Formative Assessment
  - Lesson 3: The Peat/Permafrost Scaffolded Explanation Feedback Guidance provides suggestions for feedback to facilitate student revision of their plan.
  - Lesson 6: Transfer Task Lesson 6 Rubric Zombie Fire Explanation Feedback Guidance: The Zombie Fire Explanation Feedback Guidance is excellent (Teacher Edition, page 321). The way the assessment is set up makes clear to students that the task is three-dimensional. For teachers, the rubric is set up explicitly to track three-dimensional elements and sample responses at each level (foundational pieces, linked understanding, organized understanding). Most importantly, there are suggestions for what feedback to provide and how to modify instruction based on the level and type of responses students provide.

   - Lesson 7: "Review the feedback document. Display slide R. Distribute Peer Feedback Guidelines to each student. Say, Use Peer Feedback Guidelines to help you give and receive feedback from your peers as you circulate the room. As you share, ask questions and provide feedback that helps the group to focus on the flow of energy in the system, what makes it a carbon sink, and what conditions make it likely to burn" (Teacher Edition, page 162).
- Summative Assessment
   - Some assessments (Lessons 4, 6, 9, and 11) are marked as both Formative and Summative on the Assessment System Overview but appear to be more formative.
   - Lesson 4: Students submit the Electronic Exit Ticket that includes three questions in which they make a claim regarding the relationship between dependent and independent variables (Teacher Edition, page 310).
   - Lesson 6: Students construct an explanation for the anchor phenomenon of Lesson Set 1, zombie fires. "Distribute Zombie Fire Explanation and give students a few minutes to read over the task and ask clarifying questions. Allow students to use their Progress Trackers, Gotta-Have-It Checklists, and science notebooks as resources as they complete the task" (Teacher Edition, page 144).
   - Lesson 9: Students develop a model of the flow of carbon (matter) and energy through earth's system, revise Gotta-Have-It Checklists and engage in discussion to come to consensus on the model, including feedback effects (Teacher Edition, page 186).
   - Lesson 12: In the Dead Zone Transfer Task, students develop a model of a carbon and oxygen cycle in the Gulf of Mexico (Teacher Edition, page 259).
- Self-assessment supports are present in the unit, but few support student reflection on their learning in the three dimensions. For example:
   - Lesson 2: The optional self-assessment of engagement in class discussions doesn't provide an opportunity to assess across three dimensions.
   - The Progress Tracker is used as a self-assessment as students consider how their thinking has changed over time.
   - "The student self-assessment discussion rubric can be used any time after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week" (Teacher Edition, page 270).
   - Lesson 7: "Say, Collaboration is important in the figuring out process, and reflection on how we give and take feedback can help us become better collaborators and figure out more. Scientists often work in teams and collaborate with colleagues to answer questions. Learning to give and especially receive critical feedback in a productive way takes practice. Complete Peer Feedback Self-Assessment to reflect on your strengths and weaknesses in this experience with peer feedback and the contributions of your classmates towards our focal agreement of moving science thinking forward. Collect Peer Feedback Self-Assessment as a student artifact and review. Follow up with students who may need additional support" (Teacher Edition, page 164).
   - Lesson 9: "Ask students to read through the agreements one more time and silently pick one norm that they personally will work on today. Display slide G. They should stop and jot in their science notebooks what strategies they will use to adhere to the agreement and why it is important" (Teacher Edition, page 194).
   - Lesson 11: "Say, Collaboration is important in the learning process, and sometimes reflection is needed to ensure that we are getting as much out of the experience as possible. Scientists often work in teams or collaborate with colleagues to answer questions or get their questions answered. Complete Feedback Self-Assessment to

account for your strengths and areas for improvement in this experience" (Teacher Edition, page 256).

Suggestions for Improvement
Consider better indicating when assessments are more formative versus summative/what specific portions of the assessment are formative versus summative on assessments labeled "Formative + Summative."

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	Extensive (None, Inadequate, Adequate, Extensive)

The reviewers found extensive evidence that the materials provide multiple opportunities for students to demonstrate performance of practices connected with their understanding of DCIs and CCCs because for key, claimed learning in the unit in each of the three dimensions, there are multiple student performances that provide students with iterative opportunities to demonstrate their growth in proficiency over time. Students receive both written and oral feedback from the teacher and peers. Students have opportunities to use their feedback to construct new learning and improve their performance in preparation for the next assessment opportunity. There are multiple, explicit opportunities for students to receive and respond to feedback regarding their performance.

Some examples include:
Students are provided with multiple opportunities to receive and respond to feedback throughout the unit. Related evidence includes:

- Lesson 1: Students develop an initial model of the zombie fire system and incrementally build the components, interactions, and mechanisms of their revised models in later lessons. Teacher prompts include asking students to identify the components of the zombie fire system, how matter might cycle in it, how energy might flow in it, how the components interact, and what mechanisms might explain what is happening (Teacher Edition, page 44). These prompts support students in focusing on the most important considerations for their initial model. Students revise their initial individual models (Teacher Edition, page 46).
- Lesson 3: Students can revise their explanations based on written teacher feedback. "Distribute Peat/Permafrost Scaffolded Explanation to each student. Describe how to use the questions and sentence starters as support. Collect the explanation from each student and evaluate using Explanation Feedback Guidance. Provide students with an opportunity to revise and respond to your comments on Explanation Feedback Guidance by rewriting their explanation before they use this explanation in Lesson 6" (Teacher Edition, page 98).
- Lesson 5: Students have the opportunity to revise their plans based on teacher and peer feedback. "Provide students with time to work independently on their plans. As they work,

circulate around the room and use shorthand to annotate their individual plans with feedback…Provide students with time to work independently on their plans. As they work, circulate around the room and use shorthand to annotate their individual plans with feedback" (Teacher Edition, page 119). Then, "Once every student has a draft of their plan, share Peer Feedback Protocol with them and give them time to review another classmate's investigation plan. Each student should review a peer's feedback and consider revisions to bring to the whole-class discussion" (Teacher Edition, page 119).

- Lesson 6: The materials prompt teachers to provide opportunities for students to revise their explanations later in the unit after receiving feedback and learning more about the phenomenon. "Collect Zombie Fire Explanation from each student. Provide feedback using Zombie Fire Explanation Feedback Guidance and return to students. If students struggle to construct an explanation based on evidence, provide opportunities for them to try again after investigating other carbon sinks and the carbon cycle in Lessons 7 and 8. These additional sources of evidence and application to other carbon sinks can help students to revise their thinking about zombie fires" (Teacher Edition, page 145).
- Lesson 7: Students revise small group models using feedback and refined understanding of targeted elements. "Now you will go back to your groups to revise your model. What feedback will you use? Why? They should briefly share the feedback received and ideas gained from visiting other models and discuss then revise their models. Remind students to focus on how the feedback they received helps clarify what is happening to the matter and energy in their systems and how it makes the carbon sink more likely to burn" (Teacher Edition, page 163).
- Lesson 9: Students develop a model of the flow of carbon (matter) and energy through Earth's system, revise Gotta-Have-It Checklists and engage in discussion to come to consensus on the model, including feedback effects (Teacher Edition, page 186). The lesson instructs teachers to, "Collect Global Carbon and Energy Flow Simulation as an artifact and snapshot of students' three dimensional understanding. Provide feedback using Global Carbon and Energy Flow Key and return Global Carbon and Energy Flow Simulation with feedback before day 2 of the lesson. In particular focus on questions 5- 7, giving prompts for more specific information on the scale of movement of carbon and energy (how much?, how long?, how fast?) between spheres. This will help them add complexity to their Gotta-Have-It Checklists that they will be revising on day 2" (Teacher Edition, page 198).

For the claimed learning in the unit, there are multiple opportunities for students to demonstrate their growth in proficiency over time. Related evidence includes:

- For key claimed learning in the DCIs of **LS1.C** and **LS2.B**, SEP of **Developing and Using Models**, and CCC of **Systems and System Models:**
    - Lesson 1: Students develop initial models "that illustrate and explain how energy and matter are flowing in the zombie fire systems" (Teacher Edition, page 44).
    - Lesson 6: "What to look for/listen for in the moment: Students identifying that their model needs to include relationships between matter and energy within the peat/permafrost system at various scales for explaining zombie fire. See specific components, interactions, and mechanisms in the example Gotta-Have-It Checklist" (Teacher Edition, page 138).
    - Lesson 9: Students use a quantitative model using dice to simulate the flow of carbon and energy through Earth's systems, "What to do: Collect Global Carbon and Energy Flow Simulation as an artifact and snapshot of students' three dimensional understanding. Provide feedback using Global Carbon and Energy Flow Key and return Global Carbon and Energy Flow Simulation with feedback before day 2 of the lesson. In particular focus on questions 5-7, giving prompts for more specific information on the

scale of movement of carbon and energy (how much?, how long?, how fast?) between spheres. This will help them add complexity to their Gotta-Have-It Checklists that they will be revising on day 2" (Teacher Edition, page 198).
    - Lesson 12: In the Dead Zone Transfer Task, students develop a model of a carbon and oxygen cycle in the Gulf of Mexico (Teacher Edition, page 259).
- For key claimed learning in the DCIs of **LS2.B** and **LS1.C**, SEP of **Constructing Explanations** (for science) and **Designing Solutions** (for engineering), and CCC of **Energy and Matter:** Flows, cycles, and conservation:
    - Lesson 3: Students use the *Peat/Permafrost Scaffolded Explanation* to construct an explanation about why there is so much matter and energy in the zombie fire system (Teacher Edition, page 98).
    - Lesson 5: Students use their Fires Progress Trackers to "work with their partners to construct an oral explanation based on evidence for whether or not they think peat would contain large hydrocarbon molecules (like starch)" (Teacher Edition, page 127).
    - Lesson 6: Students complete the *Zombie Fire Explanation* to develop explanations that incorporate energy and matter. "Instructions: Use evidence from your investigations to explain: (A) How was there enough matter and energy in the zombie fire system for a zombie fire to burn under ice? (B) What will happen in the future if temperatures continue to rise?" (Zombie Fire Explanation).
    - Lesson 10: Students read case studies to identify scientific reasoning that supports an explanation about fire management focusing on the cycling of carbon and energy (Teacher Edition, pages 214–218).
- For key claimed learning in the DCIs of **LS2.B** and **LS1.C**, SEP of **Planning and Carrying Out Investigations**, and CCC of **Energy and Matter:**
    - Lesson 2: Students work on planning an investigation to measure energy changes with burning fuel samples. "What to do: Following the class discussion, invite students to review their responses and then collect Investigation Planning Workspace. Sort student responses to inform grouping for the Burning Fuels investigation on day 2. Use the following three categories as a guide to sorting student responses: 1. students that demonstrate an understanding of evidence of energy AND matter and have at least one idea for a data collection tool 2. students that demonstrate an understanding of how to collect evidence of energy OR matter with or without an idea for a data collection tool. 3. students that do not yet demonstrate an understanding of what could be considered evidence of energy and matter changes with or without an idea for a data collection tool. On day 2, use the piles to create groups that distribute students from each pile across groups" (Teacher Edition, page 71).
    - Lesson 5: Students plan an investigation about photosynthesis. "What to look for/listen for in the moment: Indications of plans that will generate evidence to test student claims including: varying amounts/intensity/direct light energy…" (Teacher Edition, page 119).

Suggestions for Improvement

N/A

B.2 Ecosystems: Matter & Energy

EQuIP RUBRIC FOR SCIENCE EVALUATION

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

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)