Middle School Scope and Sequence

February 2022

Overview

The OpenSciEd Middle School Program Scope and Sequence (S&S) articulates how the middle school program is organized as performance expectations bundled in a unit, how each unit builds on what students have developed in prior units, and how the elements of the three dimensions of the Next Generation Science Standards (NGSS), disciplinary core ideas (DCIs), crosscutting concepts (CCCs), and science and engineering practices (SEPs) build coherently across the program. Building the three dimensions across the program is central in OpenSciEd. We attend to both intentional scaffolding of student learning of all three dimensions over the program and to making sure the arrangement of learning makes sense to students. We call this latter influence on the arrangement “coherence from the student’s perspective” or “coherence” for short. It is central in OpenSciEd’s program and critical to its success in motivating student learning and helping students see science as more connected to their lives.

This coherence is central in the vision of *A Framework for K-12 Science Education* (the *Framework*) and the *NGSS*. These reforms target making the science students learn more connected to their own interests, experiences, and questions, and thereby seen as more meaningful and relevant. This requires creating a mindset where students see science as bringing to bear what they know to try to make sense of the world and solve problems. Students should always be asking “what do I already know that I can use to help make sense of this new thing?” For these reasons, helping students make connections is a central aspect of three-dimensional learning. This means shifting away from viewing topics as modular and disconnected and focusing on helping students connect what they figured out in earlier units and grades to the phenomena and problems they are working on in their current unit.

In OpenSciEd, these connections are central to supporting coherence from the students’ perspective. Guidance is embedded in the supports in each OpenSciEd unit for connecting the work students did earlier in developing science ideas (DCIs, CCCs) and practices (SEPs) to use in making sense of phenomena and solving problems in the current unit, often extending what students have figured out by applying it in this new context. This document articulates the progressions of the three dimensions that define the OpenSciEd program.

Unit Performance Expectation Bundles and Unit-Unit DCI Connections

One of the first things that people often want to know about a program is how the core science ideas (DCIs) build over time. Figure 1 shows how the NGSS performance expectations (PEs) are organized into bundles corresponding to the 18 units (six per grade), how these units are sequenced, and how units build on what students have figured out so far about the DCIs in these earlier units. [Appendix A](#) provides the details for how each unit builds on what students have figured out about the DCIs in prior units.

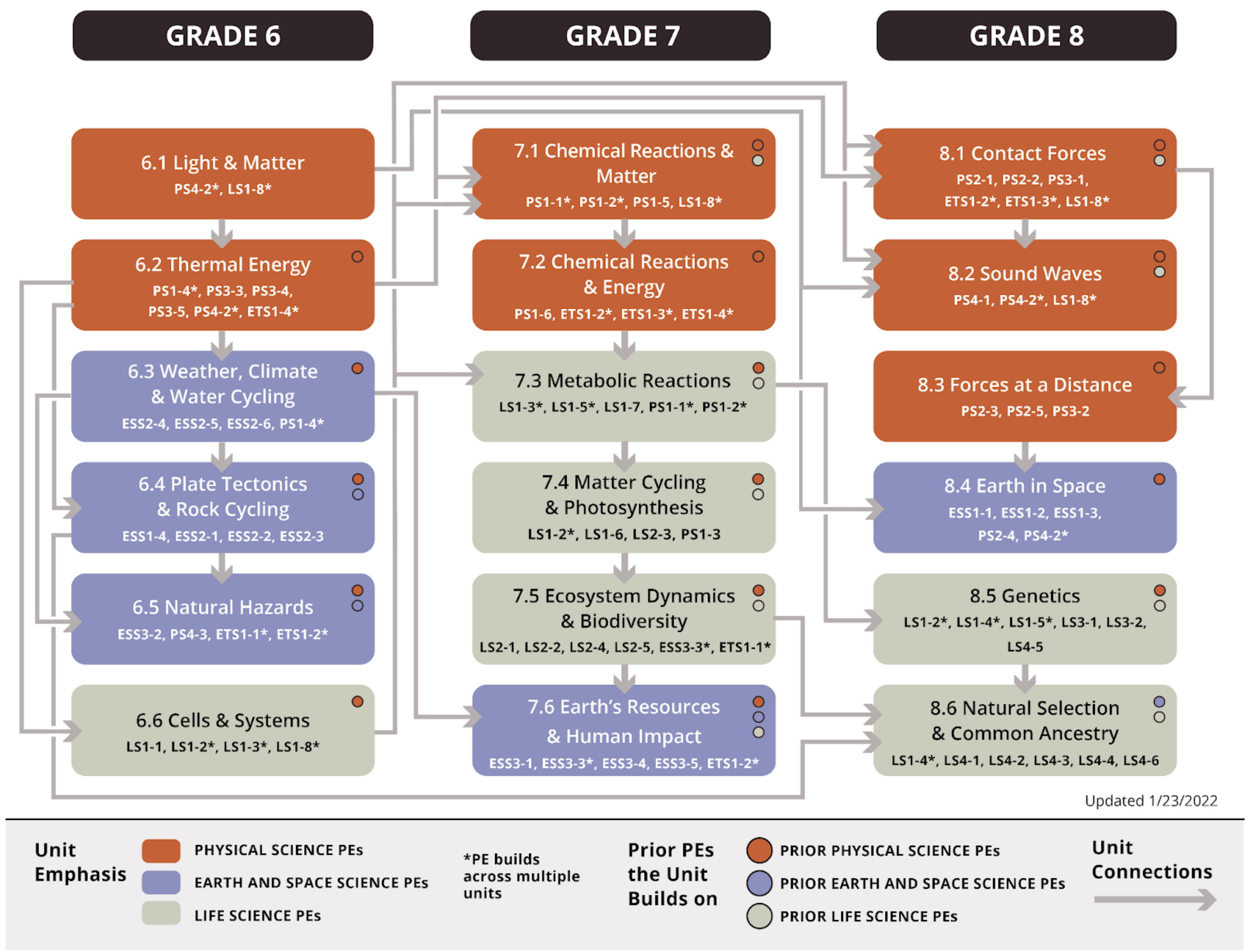

Figure 1: Scope and Sequence Map indicating PE clusters and DCI connections between units

While most units contain PEs from multiple science strands (Physical Science [PS], Earth and Space Science [ESS], or Life Science [LS]), the color shading of the unit indicates which strand is the emphasis. In addition, engineering PEs are integrated across all science strands. These are not indicated with colors, but are listed using the PE code ETS (Engineering, Technology, and applications of Science). The arrows show DCI connections between units, indicating that the later unit builds directly on what students figure out about the DCIs in the prior unit. The small dots at the top right of each unit also show connections, indicating the science strands the unit builds upon. For example, Unit 7.3 is shaded to represent that the unit emphasizes Life Science DCIs, and the dots on its top right indicate that this unit builds on both Life Science and Physical Science ideas from earlier units (6.6., 7.1, 7.2).

Why are the particular PEs bundled together in each unit?

We clustered PEs together because they contain a group of important science ideas that students need to figure out grade-level appropriate explanations for the phenomena or problems that anchor a unit. Our goal is coherence from the students' perspective, where students see the relevance of the science questions they are working on. So, rather than treating all ideas about light together in one unit, students encounter different ideas about light where those ideas become useful tools for explaining phenomena or solving problems, such as learning about the path light travels when investigating why we see what we see (unit 6.1), learning about light as a form of energy when investigating how substances warm up or cools down (unit 6.2), and investigating how light travels through space when investigating patterns in our sky (unit 8.4).

As is stated multiple times in the NGSS Appendices, the three dimensions of each PE are not intended to limit how the three dimensions are used in instruction. In other words, a PE being listed in conjunction with a unit here does not necessarily mean that all three dimensions are used the way they are described in the PE. It does mean that students are learning about the DCI while engaged in three-dimensional science learning. How the other two dimensions of the standards are built over the course of the program is described below, ensuring that students do have opportunities to learn the full scope of the learning outlined in the Framework and the NGSS.

Why are some PEs built across units (PEs marked with a "star")?

As has already been mentioned, we have developed our units so that students' learning is driven by their questions about intriguing phenomena, rather than grouping ideas by science topic that might be logical to someone who is already an expert in the field. As a result, we sometimes need to support students in building the DCI elements of PEs across multiple units. For example, we do not have a single unit that "teaches waves" (DCI PS4). While it is important for students to see some parallels between different kinds of waves (e.g., light, sound, seismic waves) eventually in this grade band, these waves models are embodied in very different kinds of phenomena and draw on very different kinds of intuitive ideas from students. Thus, we tease apart the PEs involving the waves DCIs into multiple units where students can work on a cluster of related phenomena, while helping students connect to their prior learning so they develop a coherent understanding of these science ideas. PEs for which the DCIs are assembled across units are marked with a star in the Scope and Sequence map. Appendix A explains how OpenSciEd supports students in assembling DCIs across units.

What do the arrows between units represent?

The most central connections are shown as arrows in the S&S map (Figure 1). An arrow in the map means that the latter unit *intentionally and explicitly* builds on the science ideas students have figured out in the prior unit. This means more than a simple "prerequisite" relationship. Where two units are linked with an arrow, e.g. from 6.2 to 6.4, that means that some lessons in unit 6.4 have students discuss what they figured out about the particular DCIs in 6.2 when they work on figuring out new phenomena in this later unit. The lesson explicitly asks teachers to support students using what they did in the prior unit to guide their sensemaking in the later unit, often extending what they figured out and how they worked with these ideas. In such cases, this support *depends on* students discussing and applying what they figured out in the earlier unit. The connections identified by the arrows are the ones that are most central to the sensemaking students are doing in the later units, and would require filling important gaps if students had not done the earlier unit.

For clarification, these are not the only DCI-based connections between units. The arrows represent those that would pose critical gaps in being able to do the work in the later unit without the experiences in the earlier unit. See Appendix A for a more elaborated description of the full set of opportunities for students to build DCIs across units, and Appendices B and C for details on how SEPs and CCCs build across units.

What happens if we switch the order of units?

In the past, it has been common practice to move around units in science curricula based on teacher licensure, teacher preference, or state standards. However the research base summarized in the *Framework* that guided NGSS and other three-dimensional standards document the challenges created by this approach. The *Framework* emphasizes the need for coherence and the intentional building of all three dimensions as critical for equitable science education. Therefore, OpensSciEd made the decision in development to make sure our materials would live up to a vision for science education that values and builds on the knowledge and experiences of all students as they progress from unit to unit and grade to grade. We believe this is critical for the future of science education and for the future of our nation.

Significant changes to the unit order will disrupt the coherence and scaffolded learning of the three dimensions and will take substantial work to reimplement in supports for teachers and students. In making a decision to reorder the sequence, we recommend thoughtful consideration of the resources that would be required for revision, a careful examination of priorities and policies that might be motivating such a revision, and a cost/benefit analysis that focuses on the benefits for student learning.

However, we know that there will be situations where the practical realities of implementation will mean that the sequence will need to be changed. With sufficient attention, it is possible to accomplish in a way that still would be effective for student learning. The sequence designed for the OpenSciEd middle school program is not the only possible sequence that would be effective for student learning. There are multiple sequences that, in principle, could be effective. But to support coherence it is imperative to define a sequence in which ideas can build across years in ways that make sense to students, and to support these unit to unit connections that the sequence entails, as we have done in the development of OpenSciEd. Thus, if a school or district wants to switch the order of units from the S&S embedded in OpenSciEd, some work would be needed to adapt units to support students in building complex ideas like particle-level models of chemical reactions incrementally across units. This S&S document identifies how each unit relies on earlier units. (See each unit's front matter for a description of how these dependencies play out across the unit.) Here is a summary of the types of dependencies you will find:

- The unit builds on work developing DCIs begun in earlier units. The unit may draw on a mechanism students figured out earlier (e.g., chemical reactions in 7.1 and 7.2) to extend it and make sense of phenomena in a very different context (e.g., the human body in 7.3). This may also appear as a PE where students have built part of the DCI element (see Appendix A). The most central of these are shown as arrow connections between units (shown in Figure 1, elaborated in Appendix A). The latter unit will explicitly have students refer to what they have figured out in earlier units, apply these earlier science ideas, adding to or revising the ideas in making sense of the phenomena in the current unit. Teachers would need to help students develop these earlier ideas if changing the sequence.

- The unit builds on prior work on SEPs or CCCs begun in earlier units (see Tables 2-3 and Appendices B-C for more detail on these progressions). The teacher would need to embed support in the current unit for those aspects of the SEPs or CCCs students built in the earlier units. For example, students refer to and use the way they trace matter and energy through a system, starting in 6.2, several times in later units (e.g., 6.3, 6.4, 7.3).
- The unit relies on a specific grade-level mathematics concept or practice for the key science sensemaking. For example, the unit that addresses heredity phenomena (8.5) relies on working with probability concepts as defined in CCSS mathematics, which are taught in most states in 7th grade. Teaching this unit earlier in the sequence before these CCSS mathematics standards are addressed would require that teachers support these probability concepts before starting this unit.
- The first unit of each year has a more substantial focus on establishing classroom culture and norms that support scientific discourse and students working together to engage in science practices such as consensus modeling and argumentation. Changes in the order involving first units from the year might require moving these supports for culture, norms, and discourse.

Defining the Progressions of Science and Engineering Practices (SEPs) and the Crosscutting Concepts (CCCs)

A key innovation in the *Framework* and the NGSS is that, in addition to supporting students in building the DCIs coherently over the K-12 learning experience, students are also expected to build and deepen their use of SEPs and CCCs as well. To accomplish this, students learn to use the science and engineering practices along with the crosscutting concepts, in concert with disciplinary core ideas, *throughout* their scientific work in OpenSciEd units. To ensure that these dimensions are just as important to student learning as the DCIs, each SEP and CCC is intentionally developed and then used centrally in students' science work across the program. This leads to three cases for how a unit can treat each SEP and CCC.

Intentionally Developed:

First, structures and supports for both teachers and students are included when it is first used to make sure that students are actually learning them and not just passively using them. We call this *Intentionally Developing* the SEP or CCC. These structures and supports are included whenever a new aspect of a SEP or CCC is introduced and when students need to use it in a very different context. Like the DCIs, learning to use the SEPs and CCCs should not happen all at once, so different aspects of the SEP and CCC are developed in different units and grades.

Key Use:

After students have started to build some aspect of a SEP or CCC, OpenSciEd includes intentionally structured opportunities where students are required to use that same aspect in later lessons and later units. We call this *Key Use* of the SEP or CCC and say that the SEP or CCC is *Key to the Sensemaking* of the unit. It gives students the opportunity to solidify their use of the SEP or CCC to make sense of phenomena and solve problems.

Not a Focus:

Individual science and engineering practices and individual crosscutting concepts usually work together as students figure out phenomena or problems. As described in the NGSS, "the eight practices are not separate; they intentionally overlap and interconnect" (NGSS, Appendix F, p. 3). Consequently, each unit contains many more cases where students use the SEPs and CCCs than those identified in the target PEs or in the lesson-level performance expectations. These additional uses of the SEPs and CCCs are not a focus of the unit learning, but students may apply these practices or concepts to accomplish the goals of their work in a lesson.

For example, units 6.2 and 6.3 provide explicit supports for students to develop grade-band level sophistication in the SEP *Planning and Carrying Out Investigations*. In units 6.4 and 6.5, students continue to use what they learned to plan and carry out investigations, but these two units focus on helping students develop other SEPs. Units 6.4 and 6.5 do not introduce any new aspects of this SEP, new tools for students to use, new conversations about how to engage in that practice, or assessments that involve that SEP. As a result, in the SEP and CCC progressions, we call this SEP *Not a Focus* for these units.

It is important to clarify that, like the DCIs, the development of SEPs and CCCs is not lumped together by "topic." As mentioned earlier, students should not be expected to learn everything there is to learn at this grade band about *Systems and Systems Models* or *Engaging in Argument from Evidence* all at once. Thus students will be supported in *Intentionally Developing* a particular aspect of working with systems and systems models in one unit, and then that CCC will play a *Key Use* role in later units. Before, in between, and after each of these, there may be units where that particular SEP or CCC is *Not a Focus*. Finally, this SEP or CCC will likely appear in later units as being *Intentionally Developed* when a different aspect of systems and systems models is being developed.

Table 1 elaborates the contrasts in these three cases of how a unit may treat an SEP or CCC in terms of what supports are in the unit, what teachers do, and what students do.

Table 1. Building Science and Engineering Practices and Crosscutting Concepts

	What is in the unit	What students do	What teachers do
Intentionally Develops	***The unit…*** …introduces new elements of the SEP or CCC or asks students to use it in a very different context. …includes tasks or discussions that introduce new aspects of the SEP or CCC. …contains lesson level performance expectations with this SEP or CCC. …contains assessment opportunities for this SEP or CCC.	***Students…*** … learn and use a new aspect of the SEP or CCC . …are assessed on this SEP or CCC as part of a 3D assessment.	***Teachers…*** …support students in tasks and discussions involving new aspects of the SEP or CCC . …provide feedback on students' performance of the SEP or CCC .
Example	Unit 6.2 *intentionally develops* the SEP of an aspect of Developing and Using Models. The unit provides explicit instruction and scaffolds to support students in modeling particle-scale mechanisms that result in observable heating and cooling phenomena.		
Key Use	***The unit …*** …includes the SEP or CCC in a central role in students' sensemaking in the unit, and so may contain lesson level performance expectations that include it.. …provides opportunities for students to have more experience working with the SEP or CCC through its use in multiple lessons. ***But, the unit…*** … does *not* introduce new elements of the SEP or CCC.	***Students…*** …use the SEP or CCC in ways that are not substantially different in terms of the elements they draw on or the contexts in which they used it in earlier units. …reinforce their understanding of it with substantial opportunities to use it again.	***Teachers…*** …continue to provide support and feedback for students on their use of the SEP or CCC. … may fade scaffolding for it (if appropriate).

	What is in the unit	What students do	What teachers do
	..does *not* ask students to use the SEP or CCC in a very different context from earlier units.		
Example	Unit 6.2 is a *key use* of the SEP Asking Questions and Defining Problems. Students use this SEP in ways similar to the prior unit, and no new aspects of the practice are introduced. But this SEP is central to the work students are doing in the unit.		
Not a Focus	***The unit...*** ...may expect students to use the SEP or CCC, but not as part of the major work students do. ... may not mention the SEP or CCC at all.	***Students...*** ... may use the SEP or CCC but it is not central in their work, ... or may not be asked to use the SEP or CCC in this unit.	***Teachers...*** ... do not focus instruction or scaffolding on the SEP or CCC.
Example	Unit 6.1 *does not focus* on the SEP Planning and Carrying Out Investigations. While students do conduct investigations, the teacher carries the weight for that work, and this unit focuses on other SEPs. This practice does not appear in lesson level performance expectations or assessment guidance.		

Tables 2 and 3 on the following pages use this three category scheme in Table 1 to summarize the progression of the SEPs and CCCs respectively in the OpenSciEd Program.

Table 2. Summary of the Progression for the SEPs

Unit	Asking Questions & Defining Problems	Developing & Using Models	Planning & Carrying Out Investigations	Analyzing & Interpreting Data	Using Math & Computational Thinking	Construct. Explanations & Designing Solutions	Engaging in Argument from Evidence	Obtaining, Evaluating & Comm. Info.
6.1	●	●	○	○	○	●	○	○
6.2	◐	●	●	●	○	●	◐	○
6.3	◐	●	●	●	◐	●	○	◐
6.4	◐	●	○	●	●	●	◐	○
6.5	◐	◐	○	◐	●	◐	●	●
6.6	◐	●	◐	●	○	◐	◐	◐
7.1	◐	◐	●	●	○	●	●	○
7.2	●	◐	◐	●	○	◐	◐	◐
7.3	◐	◐	◐	●	○	◐	◐	○
7.4	◐	●	◐	○	○	◐	◐	◐
7.5	●	◐	◐	◐	●	◐	◐	◐
7.6	●	◐	○	◐	●	◐	◐	◐
8.1	◐	◐	◐	●	○	◐	◐	○
8.2	○	◐	○	◐	●	○	◐	○
8.3	●	◐	●	◐	◐	◐	○	○
8.4	○	●	◐	●	○	○	○	◐
8.5	◐	◐	◐	○	●	◐	○	●
8.6	◐	◐	◐	●	○	●	◐	◐

● **Intentionally Developed** ◐ **Key Use** ○ **Not a Focus**

Table 3. Summary of the Progression for the CCCs

Unit	Patterns	Cause and Effect	Scale, Proportion, and Quantity	Systems and Systems Models	Energy and Matter	Structure and Function	Stability and Change
6.1	○	◐	○	●	○	●	○
6.2	●	◐	◐	●	●	●	○
6.3	◐	●	○	●	●	○	●
6.4	◐	◐	●	○	○	○	●
6.5	◐	◐	○	◐	○	◐	●
6.6	◐	◐	◐	◐	○	◐	○
7.1	◐	○	●	○	◐	○	○
7.2	◐	◐	◐	◐	●	○	○
7.3	◐	◐	○	●	◐	◐	○
7.4	◐	○	○	●	●	○	○
7.5	◐	◐	○	◐	○	○	●
7.6	◐	◐	◐	◐	◐	○	●
8.1	◐	◐	○	◐	◐	●	●
8.2	◐	◐	●	○	◐	○	○
8.3	◐	●	◐	◐	◐	○	○
8.4	●	◐	●	●	○	○	○
8.5	◐	◐	◐	○	○	◐	○
8.6	◐	◐	○	○	○	◐	◐

● **Intentionally Developed** ◐ **Key Use** ○ **Not a Focus**

How to Use The Scope and Sequence Appendices

As explained above, coherence from the students' perspective, where we help students connect new things they are learning to what they have already figured out, plays a central role in OpenSciEd. The OpenSciEd Scope and Sequence provides key guidance about how each unit contributes to the development and/or draws on what students have already figured out concerning various parts of the DCIs, CCCs, and SEPs defined in NGSS needed to fully prepare students to meet the performance expectations of NGSS. The figure and tables above display summaries of the progressions for each of the three NGSS dimensions, DCIs (Figure 1), SEPs (Table 2) and CCCs (Table 3). The appendices provide more detailed explanations of the information in the figure and tables.

Teachers can use the information about what is new (and therefore supported and assessed) and what is expected based on students' prior learning, as articulated in these appendices, to plan their teaching of the unit for their own students and differentiate where more or less support may be needed. Schools or districts can use these appendices to develop their scope and sequence if they plan to customize the OpenSciEd scope and sequence. The Scope and Sequence identifies the important supports for building across units and across years that need to be considered in customizing the scope and sequence.

The information in this scope and sequence is drawn from the explanations within each unit in the *Teacher Background Knowledge* section that begins each unit. The Scope and Sequence pulls the information from all 18 units and connects it all together to tell the story in one place of how the OpenSciEd program helps students build each dimension step by step across the 18 units in ways that make sense and are meaningful to students.

- Appendix A: DCI Progressions: This appendix explains how each unit plays a role in developing DCI elements that build on prior units. The DCI Progressions expand on the S&S map identifying how PEs are assembled across units and how each unit builds on prior units in terms of the DCI-based connections.
- Appendix B: How OpenSciEd Units Support the Progressionsof SEPs and CCCs. This appendix expands on Table 1 to define what you will see in each unit in terms of the guidance a unit provides and the expectations for prior learning when the unit Intentionally Develops or draws on Key Use of an SEP or CCC.
- Appendix C: SEP Progressions describes how students build the elements of each SEP in each unit across the program, detailed in terms of NGSS elements of SEPs.
- Appendix D: CCC Progressions describes how students build the elements of each CCC in each across the program, detailed in terms of NGSS elements of CCCs.
- Appendix E describes the process for developing the OpenSciEd Scope and Sequence.

Additional Resources

To read more about the OpenSciEd program and its rationale:

- To read more about the pedagogical approach in OpenSciEd Middle School that this S&S supports, see the OpenSciEd Teacher Handbook.
- To see more about the development of the OpenSciEd Middle School Scope and Sequence, including examples of how the unit designs support unit-to-unit connections, see the OpenSciEd webinar on the MS S&S.
- To read more about the history and overall approach of the OpenSciEd project, read this article (free download):
    - Edelson, D. C., Reiser, B. J., McNeill, K. L., Mohan, A., Novak, M., Mohan, L., Affolter, R., McGill, T. A. W., Bracey, Z. E. B., Noll, J. D., Kowalski, S., Novak, D., Lo, A. S., Landel, C., Krumm, A., Penuel, W. R., Horne, K. V., González-Howard, M., & Suárez, E. (2021). Developing research-based instructional materials to support large-scale transformation of science teaching and learning: The approach of the OpenSciEd middle school program. *Journal of Science Teacher Education*, 32(7), 780-804. https://doi.org/10.1080/1046560X.2021.1877457
- "Coherence from the students' perspective" is defined by Brian Reiser and the NextGen Science Storylines group in their work on NGSS science storylines. To read more about the storylines approach on which the OpenSciEd pedagogical approach is based, read this article (free download):
    - Reiser, B. J., Novak, M., McGill, T. A. W., & Penuel, W. A. (2021). Storyline units: An instructional model to support coherence from the students' perspective. *Journal of Science Teacher Education*, 32(7), 805-829. https://doi.org/10.1080/1046560X.2021.1884784
- To read about how the storylines model used in OpenSciEd reflects and builds on ideas in project-based learning, read this article (free download):
    - Penuel, W. R., Reiser, B. J., McGill, T. A. W., Novak, M., Van Horne, K., & Orwig, A. (2022). Connecting student interests and questions with science learning goals through project-based storylines. *Disciplinary and Interdisciplinary Science Education Research*, 4(1), 1-27. https://doi.org/10.1186/s43031-021-00040-z

Appendix A: DCI Progressions

In this Appendix, we expand on the S&S graphic in Figure 1 showing the bundling of PEs by unit and the DCI-based connections between units to identify (a) how PEs are assembled across units and (b) how each unit builds on the work of prior units in developing DCIs.

How does OpenSciEd help students build some performance expectations across units?

Here we consider how students incrementally build the DCIs of the performance expectations that appear in more than one unit (indicated in the S&S map with a "*"). While most PEs are revisited across multiple units to provide additional opportunities to reinforce them, for 14 of the 59 middle school PEs, the DCI components of those PEs are intentionally developed across several units. As a result, the combination of units listed for the PE would be necessary to completely provide students the opportunity to completely build the DCI elements of the PE. These PEs with DCIs that are intentionally built across units are shown in Tables A.1, A.2, and A.3.

Table A.1 Building Physical Science DCIs Across Units

PS PE	Units	The Progression of DCI Elements Across Units
MS-PS1-1	7.1, 7.3	**DCI elements:** *PS1.A: Structure and Properties of Matter* • *Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.* • *Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).* **Progression:** In 7.1, students figure out how atoms that make up molecules and can be rearranged in chemical reactions. In 7.3 students figure out what kinds of molecules are used in cells to get energy that is transferred in chemical reactions. The complexity of the molecules students investigate also increases. In 7.1 the molecules are relatively simple structures, made of a few atoms, while many of those investigated in 7.3 have extended repeating sub-structures made of many more atoms.

<table>
<tr><th>PS PE</th><th>Units</th><th>The Progression of DCI Elements Across Units</th></tr>
<tr><td>MS-PS1-2</td><td>7.1, 7.3</td><td>DCI Elements:
PS1.A: Structure and Properties of Matter
Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
PS1.B: Chemical Reactions
Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
Progression: In 7.1, students figure out how the atoms that make up substances are rearranged in chemical reactions and how this can lead to substances with different properties. In 7.3, students extend the model to see how chemical reactions occur in cells in living things as they process food.</td></tr>
<tr><td>MS-PS1-4</td><td>6.2, 6.3</td><td>DCI Elements:
PS1.A: Structure and Properties of Matter
Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
PS3.A: Definitions of Energy
The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary)
The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary)
Progression: In 6.2, students figure out how the motion and spacing of the particles in a substance varies between its solid, liquid, and gas form. Students develop a model explaining temperature differences in a substances in terms of the kinetic energy of its particles. Students explain temperature change as transferring thermal energy through particle collisions. In 6.3, students figure out how changes in state occur when thermal energy is added or removed.</td></tr>
</table>

PS PE	Units	The Progression of DCI Elements Across Units
MS-PS4-2	6.1, 6.2, 8.2, 8.4	**DCI Elements:** *PS4.A: Wave Properties* • *A sound wave needs a medium through which it is transmitted.* *PS4.B: Electromagnetic Radiation* • *When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.* • *The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.* • *A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.* • *However, because light can travel through space, it cannot be a matter wave, like sound or water waves.* **Progression:** Light and sound are very different in terms of students' intuitive ideas and the real-world phenomena that involve them. Therefore, although NGSS combines them in waves DCIs, we treat some aspects separately. First, in 6.1, students figure out that when light shines on an object, it is reflected and/or transmitted through the object, depending on the object's material. Students also figure out that light travels a straight-line path, except at surfaces between different transparent materials, where the path bends (light refracts). In 6.2, students figure out that in addition to being reflected and/or transmitted, light can also be absorbed by an object. In 8.2 students figure out that a sound wave needs a medium through which it is transmitted. In 8.4, students figure out that light can travel through space, unlike sound. Students figure out that different colors of light can be combined together and separated from one another, and that different colors of light bend a different amount (refract) as that light enters or exits different media.

Table A.2 Building Life Science DCIs Across Units

LS PE	Units	The Progression of DCI Elements Across Units
MS-LS1-2	6.6, 7.4, 8.5	**DCI Elements:** *LS1.A: Structure and Function* • *Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.* **Progression:** Students build the basic idea in 6.6, figuring out that structures that make up the cell (cell wall & membrane) help achieve cell functions of controlling what enters and exits cells. In 7.4, students revisit this idea and add the role of the structures of mitochondria and chloroplasts (explicitly mentioned in the PE clarification statements) in obtaining food and energy. Then in 8.5, when investigating chromosomes students add another important structure in the PE, the nucleus, and figure out its function in holding the molecules needed to pass traits to offspring.

MS-LS1-3	6.6, 7.3	**DCI Elements:** *LS1.A: Structure and Function* • *In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.* **Progression:** In 6.6, students figure out that the body is a system of multiple interacting subsystems, and that these subsystems are groups of cells that work together to form tissues that are specialized for particular body functions. Students figure out interactions between cells and systems in the context of repair and growth related to the circulatory, muscular and nervous systems. In unit 7.3, students figure out interactions between cells, tissues, organs and systems in the context of using and storing food for energy related to the digestive, excretory, circulatory, muscular and respiratory systems.
MS-LS1-4	8.5, 8.6	**DCI Elements:** *LS1.B: Growth and Development of Organisms* • *Animals engage in characteristic behaviors that increase the odds of reproduction.* • *Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.* **Progression:** In 8.5 students investigate reproductive structures in plants and figure out how the structures of flowers can interact specifically with different pollinators. In 8.6, students figure out how animals engage in behaviors that increase their likelihood they can reproduce.
MS-LS1-5	7.3, 8.5	**DCI Elements:** *LS1.B: Growth and Development of Organisms* • *Genetic factors as well as local conditions affect the growth of the adult plant.* **Progression:** In 7.3, students figure out how food intake affects the growth of animals. They develop a model to explain how the body breaks food molecules and rearranges their components through chemical reactions to build or repair body structures. In 8.5 students investigate how genetic information plays a major role in how the building blocks of proteins are rearranged. In 8.5 students investigate the combination of local environmental effects and genetic influences on plant growth, in musculature in animals, and other trait variations in animals.
MS-LS1-8	6.1, 6.6, 7.1, 8.1, 8.2	**DCI Elements:** *LS1.D: Information Processing* • *Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.* **Progression:** In 6.1 students figure out how receptors respond to light. In 6.6 students figure out how nerve cells relay signals from receptors to the brain to perceive touch and pain and how injuries can interfere with that process. Unit 7.1 addresses how receptors detect and respond to chemical inputs (e.g., smell). Unit 8.1 builds by adding heat and pressure as additional mechanical inputs for two additional types of sense receptors. Unit

		8.1 also addresses how signals are processed in the brain, resulting in immediate behaviors or memories. Unit 8.2 adds mechanical inputs detected in perception of sound.

Table A.3 Building Earth and Space Science DCIs Across Units

ESS PE	Units	The Progression of DCI Elements Across Units
MS-ESS3-3	7.5, 7.6	**DCI Elements:** *ESS3.C: Human Impacts on Earth Systems* • *Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.* • *Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.* **Progression:** In 7.5 students figure out that human activities have significantly altered the biosphere, damaging some natural habitats and causing the extinction of other species. Students also investigate how changes to Earth's environments can have different impacts (negative and positive) for different living things. Students focus on understanding the problem, which involves humans altering the biosphere in ways that negatively impact other species and alterations in their own communities. Students also encounter ways humans farm for food that positively support biodiversity. Unit 7.6 focuses on natural water resources, changing precipitation and climate, and human impacts. Students figure out that typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered to prevent this.

How does each OpenSciEd unit build on what students have figured out about the DCIs in prior units?

The section describes how each unit builds on prior work begun in earlier units. As mentioned above (in the section *What do the arrows between units represent?*), an arrow between two units means that the latter unit explicitly asks students to talk about what they did in a prior unit in order to apply those ideas and extend them in the new context of the latter unit. We refer to these connections shown as the arrows as key connections in that the work in the latter unit depends on what students figured out in the earlier unit.

There are additional unit-to-unit connections important to coherence that are not shown by an arrow. For example, the arrow from Unit 7.3 to Unit 8.5 in the S&S diagram makes it clear that Unit 8.5 builds directly on Unit 7.3. In 8.5, students figure how chromosomes make proteins by drawing on what they figured out earlier about how atoms can be rearranged in a chemical reaction in living things in 7.3. But if we dig a little deeper, we see that when students developed these ideas in 7.3, they were drawing on ideas developed in even earlier units. When students figured out chemical reactions in living things in 7.3, they drew on the model of matter and energy in chemical reactions in 7.1 and 7.2 in the context of physical systems. So the arrow from 7.3 to 8.5 means that students will directly draw on ideas they used most recently in Unit 7.3, but the teacher guidance will also refer to earlier work they did on chemical reactions in Units 7.1 and 7.2. Thus, there are more connections than those shown just by the arrows. However, to keep the map from being more confusing, we draw arrows only from the most recent use of each model idea that students will need to draw on.

Tables A.4, A.5 and A.6 identify the ways the units in each grade unit build on prior units, both those shown by arrows and those that are not reflected with arrows. (See the unit front matter, *Where does this unit fall within the OpenSciEd Scope and Sequence?* and *What should my students know from earlier grades or units?* for more information on each unit.)

This appendix focuses on how each unit builds on prior work on the DCIs in the OpenSciEd program. Each unit also builds on students' prior work developing SEPs (discussed in Appendix C) and in developing CCCs (discussed in Appendix D). Many units also build in critical ways on science ideas and practices developed in prior grade bands in K-5. To learn about these connections please see the Teacher Background Knowledge in each unit.

Table A.4 How Each Grade 6 Unit Builds on Prior Units

Unit	Key connections (arrows)	How this units builds on prior units
6.1 Light and Matter	NA	NA
6.2 Thermal Energy	6.1 → 6.2	In 6.2, students build on the ideas about light begun in 6.1. In the new context of particle models and energy transfer in 6.2, students figure out how absorption of light occurs at the particle level (absorbing light increases the kinetic energy of the particles of the substance).
6.3 Weather, Climate & Water Cycling	6.2 → 6.3	In 6.3, students build on models from 6.2 explaining how energy can be transferred through light (radiation) and conduction. Students draw on these mechanisms in the new context of weather and climate to develop an additional model (convection) explaining how energy is transferred through a system. Students also build on ideas from 6.2 about how particles move in different states of matter and at different temperatures to figure out why water changes state at a particular temperature when thermal energy is added or removed to it. The resulting flow of matter through convection in Earth's atmosphere and in its oceans that move water into and out of the atmosphere are fundamental to explaining weather and climate-related phenomena. The weather and climate ideas developed here are drawn on later in 6.5 and later units.
6.4 Plate Tectonics & Rock Cycling	6.2 → 6.4 6.3 → 6.4	In 6.4, students apply their model of thermal energy flow from 6.2 to analyze the role of energy in plate tectonics. They reason that there must be a source of energy deep in Earth's interior that transfers energy toward the cooler surface and causes the movement, bending, cracking, and uplift of plate material. Students extend their model of state change from 6.3 to explain why solid rock at and below the surface, made of different substances, melt at different temperatures. They also consider how the combined effects of elevated temperature and the weight of rock material above might push on the rock below, causing it to behave more like liquid in some cases vs. others. This extends their model of convection from 6.3 developed to explain movement of air masses. Students also use ideas from 6.3 about prevalent wind and precipitation patterns in different parts of the earth to help explain why different rates of erosion may be occurring in different places.
6.5 Natural Hazards	6.4 → 6.5	In 6.5, students build on models from 6.4 about earth system processes that cause motion in the earth's crust to explain how this release of energy can form a tsunami wave, modeling how geologic processes can explain where natural hazards are likely to occur. Students apply models of energy transfer from 6.2 to develop their models of energy in tsunami waves. Students also draw on weather and climate ideas from 6.3 to investigate natural hazards driven by weather and climate processes such

Unit	Key connections (arrows)	How this units builds on prior units
		as hurricanes, flooding, storms, hail, droughts, and tornadoes to inform their 6.5 final projects. Students also draw on ideas about air temperatures and precipitation patterns in this work.
6.6 Cells & Development	6.2 → 6.6	In 6.6, students build on what they figured out in 6.2 (extended in 6.3) to analyze and explain how matter can move through a system. Students draw on how they used crosscutting concepts and practices in these earlier analyses of systems to analyze the human body system. Students develop a system model that identifies the different parts of the system and explain how the parts interact to help the body heal. They use the idea of structure and function as they did in these earlier units to tie each part's structure to its function and reason about how injury to the part would affect the body's function.

Table A.5. How Each Grade 7 Unit Builds on Prior Units

Unit	Key connections (arrows)	How this units builds on prior units
7.1 Chemical Reactions & Matter Transformations	6.2 → 7.1 6.6 → 7.1	In 7.1, students use and build upon the particle model of matter developed in 6.2. Students draw on the idea that matter can get into and out of open systems but not closed systems developed in 6.2 to tease apart different candidate models for how gas forms when a bath bomb is added to water. Students draw on their particle level model of water from 6.2 and 6.3 that water is made up of small particles that are all the same type and on their model of how when temperature changes, the speed and spacing between particles changes. In this unit, students figure out that water is a molecule made up of atoms of hydrogen and oxygen, and model how these atoms in liquid water can rearrange to make new molecules (each of which is a gas at room temperature) by adding energy (both thermal and electrical). Students also revisit the model of cell receptors developed in 6.6 in which cells perceive stimuli such as light and touch. In 7.1, students extend the model to include chemical reactions as a mechanism through which cells can detect and respond to chemical inputs such as when a person smells an odor.
7.2 Chemical Reactions & Energy	7.1 → 7.2	In 7.2, students apply what they have figured out from the previous unit 7.1 about how a chemical reaction occurs to determine that a chemical reaction is responsible for the ability of an MRE (Meal, Ready to Eat) to heat the food without an external heat source. In investigating other substances that may undergo chemical reactions to find a candidate for their homemade heater students figure out that some reactions result in energy transfer to another system, while other reactions result in energy transferring from another system.

Unit	Key connections (arrows)	How this units builds on prior units
		Students use the particle models developed in 6.2 and extended in 6.3, 6.4, and 7.1 to create models to explain how energy transfers between parts of an MRE flameless heater system, which allows for them to map those ideas to the designs for their homemade flameless heaters.
7.3 Metabolic Reactions	6.6 → 7.3 7.2 → 7.3	In 7.3, students figure out interactions between cells, tissues, organs and systems in the context of using and storing food for energy related to the digestive, excretory, circulatory, muscular and respiratory systems. Students build on their models developed In 6.6 of the body as a system of multiple interacting subsystems, where each subsystem is a group of cells that work together to form tissues specialized for particular body functions. In 7.3, students figure out interactions between cells and systems in the context of repair and growth related to the circulatory, muscular and nervous systems. In 7.1 and 7.2 (drawing on the particle model from 6.2), students figured out how atoms that make up molecules can be rearranged. In 7.3, students extend that model to figure out how chemical reactions occur in cells in living things as they process food. Students figure out what kinds of molecules are used in cells to get energy that is transferred in chemical reactions. The complexity of the molecules students investigate also increases. In 7.1 the molecules are relatively simple structures, made of a few atoms, while many of those investigated in this unit have extended repeating sub-structures made of many more atoms.
7.4 Matter Cycling & Photosynthesis	7.3 → 7.4	In 7.4, students extend what they figured out about how chemical reactions in our bodies break down food molecules into smaller pieces to be used for different functions from 7.3 to explain how plants get food. This unit builds directly on disciplinary ideas students have developed in multiple prior units about how matter is made of moving particles (6.2), the role of cells in living things (6.6), how chemical reactions rearrange matter but do not create or destroy it (7.1, 7.2), and how chemical reactions occur in living things (7.3). In building these models, students investigate how plants get the matter to make the food molecules like carbohydrates, proteins, and fats that they determine are in the foods we eat that come from plants. Students use the idea from 6.2 and 7.2 that matter does not appear or disappear to reason that since food molecules do not enter the plant, plants must be making them from other inputs containing those atoms. Students explain how gases enter plant cells for the chemical reaction plants use to make food drawing on the ideas of cell structure and function (from 6.6) and the role of permeable membranes in cells (from 7.3). Students also build on their prior work with analyzing structures and functions in cells and extend that model to identify the role of chloroplasts and mitochondria. Students apply the ideas from their system models of the flow of matter and energy developed in earlier units. Prior to this unit, students have developed system models within a life science phenomenon in 6.6 and 7.3. Students also

Unit	Key connections (arrows)	How this units builds on prior units
		built system models in 6.2 when determining what components of a cup system affect the temperature of the liquid inside, and 6.3 when figuring out what causes storms. In this unit, students develop a system model that involves the interactions of both living and nonliving components.
7.5 Ecosystems Dynamics & Biodiversity	7.4 → 7.5	In 7.5, students leverage ideas about food webs, producers, consumers, and interactions between these organisms from units 7.3 and 7.4 to investigate stability and disruptions in ecosystems.
7.6 Earth's Resources & Human Impact	6.3 → 7.6 7.5 → 7.6	In 7.6, students draw on and extend their models of the water cycle (6.3) by thinking about how this cycle can change with changes in global temperatures. Students reinforce a distinction between weather and climate (6.3) and look at long-term changes in two climate variables—temperature and precipitation. Students build on the understanding of human impacts on the biosphere (7.5) and extend it to investigate the role of consumption of natural resources. The unit also builds on chemical reactions (7.1, 7.2) when investigating burning fossil fuels for energy and on the carbon cycle (begun in 7.4).

Table A.6. How Each Grade 8 Unit Builds on Prior Units

Unit	Key connections (arrows)	How this units builds on prior units
8.1 Contact Forces	6.2 → 8.1 6.6 → 8.1	In 8.1, students leverage ideas about the particle nature of matter (6.2, 7.1, 7.2), and how energy can be transferred through particle-level collisions (conduction, 6.3) to develop models explaining effects on macro level objects in collisions. Students draw on their models of how kinetic energy transfers through particle collisions from 6.2 and 6.3 as a starting point to explore forces in collisions. Students figure out that collisions involve energy transfer and can cause the objects involved to change motion. Students identify that a force must be applied to an object to cause its shape to change in a collision, and they investigate the force interactions between objects throughout the unit. Students later figure out that when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from each object. They also draw on ideas about temperature as a measure of the average kinetic energy of particles and extend their model of energy transfer occurring through particle-level collisions that are producing force interactions to explain what causes a moving object to slow down as a result of air resistance and surface friction and how temperature also increases as a result. Students also draw on prior analyses of how cells can detect stimuli in the environment from 6.6 and 7.1. Students draw on ideas from 6.6 about how

Unit	Key connections (arrows)	How this units builds on prior units
		neurons function, where they are located, and some of their structures (axon and neurons) and extend them to explain the sense of touch, and how we sense pain, temperature, and pressure and how neurons transmit signals to the brain. The unit also extends work in 7.2 on engineering design and leverages students' ideas about the role of criteria, constraints, stakeholders, and tradeoffs in the engineering design process.
8.2 Sound Waves	6.1 → 8.2 6.6 → 8.2 8.1 → 8.2	In 8.2, students leverage ideas about the transfer of energy between colliding objects from 6.2 and 8.1 and the idea that all solid objects are elastic (8.1) to figure out how energy is transferred when sound travels. This model also relies on what students figured out in 6.2 about the different spacings between particles for solids, liquids, and gases. Students draw on their prior models to model how energy is transferred through a medium by collisions between particles that make up the substance, and how these particle collisions are detected as sound. These models also build on the idea from 6.2 and 8.1 that when two objects collide, each one exerts a force on the other that can cause energy to be transferred between the objects and build the model of how collisions between particles allow for the transfer of energy across a medium. Students explain the transfer of energy in sound phenomena as transfer of kinetic energy through particle collisions drawing on their models from 6.2 and 8.1. Students also use the idea of conservation of energy from 6.2 and 8.1 to figure out that energy transfer from a drumstick to a drum means that the drumstick has less energy after colliding with the drum. Students also build on this idea to analyze data and figure out that in order to get an object to start moving or vibrating, energy has to be transferred to that object. Students' models also extend the idea from 8.1 that solids are elastic (i.e., that they change shape in response to a force being applied to them) to explain how a greater force being applied on that solid causes a greater change in shape. Students use these understandings to explain the difference between how objects vibrate when making a louder versus a softer sound, and connect this louder sound with a stronger force being applied to the object.
8.3 Forces at a Distance	8.1→ 8.3	In 8.3, students extend their model of contact forces to explain how forces can affect an object's motion without touching it — forces at a distance. This draws on the model students developed in 8.1 that explains how contact forces lead to changes in motion of objects; how energy is transferred through contact forces; and that for every force applied to an object there is an equal and opposite force to another object or part of the system. Students also revisit the contact forces explanation of sound, where particle collisions cause vibration, to explain forces and energy transfer in a speaker that produces sound.

Unit	Key connections (arrows)	How this units builds on prior units
8.4 Earth in Space	6.1 → 8.4 8.3 → 8.4	In 8.4, students build on the ideas about distance forces and field-based thinking they developed in 8.3. The mechanism of distance forces is a key component students use to develop their models of how gravitational forces explain orbits and larger scale system organization and motion due to gravity. In 8.4, students also build on their ideas about atmosphere from 6.3. Students investigate how the presence or absence of an atmosphere as well as changes in the atmosphere can affect the apparent color of the Moon during a lunar eclipse and in other phenomena in the sky, such as rainbows and sun dogs. Students also build on their earlier ideas about light developed in 6.1. From the beginning of the unit, student questions emerge and spiral through the rest of the unit, beckoning learners to explain changing colors and patterns of light in the sky. This motivates them to explain how light interacts with the changing position of objects in the Earth-Sun-Moon system to make the Moon appear redder in the sky. Students build on prior work from 6.1 to more fully build out their models explaining reflection, absorption, and transmission of light through the atmosphere and water.
8.5 Genetics	7.3 → 8.5	In 8.5, students build on their prior physical science work on chemical reactions and molecular structure. Students draw on their ideas of how molecules are composed of atoms (7.1, 7.2) when investigating the structure of chromosomes. Students draw on their models of chemical reactions rearranging connections between atoms (7.1, 7.2, 7.3) when they figure out how chromosomes make proteins and how different molecular structures in chromosomes determine the shape of the protein produced. Students also build on their models of how our bodies break down food molecules into smaller pieces that can be used for different functions (7.3). Students also leverage their ideas about cell structure and function (6.6) to guide their investigation of muscle cells and explain how muscles function. Students build on their earlier model of how cells “grow and divide” (6.6) to explain how sex cells combine and the resulting cell becomes a baby calf.

Unit	Key connections (arrows)	How this units builds on prior units
8.6 Natural Selection & Common Ancestry	6.4 → 8.6 7.5 → 8.6 8.5 → 8.6	In 8.6, students build a natural selection model that relies on earlier models developed in 7.5 and 8.5. They use their understanding of interdependent relationships in ecosystems from 7.5 to make sense of how different organisms and populations depend on their interactions with other living things and with their environment, including how organisms compete for limited resources, and how these dependencies constrain growth and reproduction. They also draw on their model from 8.5 of how genes (passed on from parents to offspring through chromosomes) control the production of proteins that affect an individual's traits, and how environmental and genetic factors contribute to the variety we see within populations. They build on these understandings in this unit to figure out how inherited traits vary within populations and between different populations, and how natural selection can influence the distribution of these traits. Students also draw on ideas from 6.4 about the history of Earth, plate tectonics, and large-scale system interactions when they analyze and interpret fossil data from different ages in Earth's history to connect fossil data as evidence for evolutionary processes.

Appendix B: How OpenSciEd Units Support the Progressions of SEPs and CCCs

This Appendix expands on the definitions from Table 2 to identify the particular criteria for classifying how a unit treats an SEP or CCC. This appendix explains what supports are available in each unit that teaches (intentionality develops) new aspects of SEPs or CCCs, draws on what students are expected to have already learned about them in earlier middle school units to accomplish making sense of phenomena or solving problems (key use), or focuses on other SEPs or CCCs.

(A) The Unit Intentionally Develops the SEP or CCC

There are several criteria that reflect cases where a unit Intentionally Develops a particular SEP or CCC. These have in common that students need to extend or broaden their current ideas and ways of using an SEP or CCC to do the work of the current unit. That is, the unit contains tasks and supports for something students need to learn about the SEP or CCC.

Why is this important? The Intentionally Developed label indicates what issues to attend to in skipping or reordering OpenSciEd units. If a unit Intentionally Develops an SEP or CCC and that unit is skipped, students will miss something important about the SEP or CCC that later units and the middle school grade band PEs rely on. Consequently, it will be necessary to address those aspects of the SEP or CCC in some other way. Similarly, if the unit sequence is changed, teachers should check where later units assume some prior development of the SEP or CCC in this unit. Teachers would need to fill in that preparation in some way for students to succeed in later units that depend on this.

A unit that Intentionally Develops a particular SEP or CCC typically includes several of the following five characteristics.

1. ***Introduces and supports new elements:*** Units that Intentionally Develop an SEP or CCC may support students in working with an element of that SEP or CCC for the first time in the middle school grade band. For example, students begin work with the practice *Developing and Using Models* (SEP 2) in units 6.1 and 6.2. But in unit 6.3 students engage explicitly with an element of modeling (SEP 2.3) that they have not focused on earlier in the program. In this element (SEP 2.3) students evaluate the limitations of a model and there are explicit conversations about this aspect of modeling. Thus, we label unit 6.3 as Intentionally Developing the SEP of *Developing and Using Models*.

2. ***Using the practice or concept in a very different context:*** In some cases the elements of SEPs and CCCs in NGSS Appendices F and G do not capture all the important shifts in thinking for students in learning to apply the practice or concept. The OpenSciEd progressions identify additional cases where support is needed to help broaden how students think about and use an SEP or CCC. Thus, units that Intentionally Develop an SEP or CCC may support students in working with the SEP or CCC in a very different type of context. For example, OpenSciEd units involve students in developing and using models to explain phenomena in many units. In the first units in 6th grade, 6.1 and 6.2, students' models all explain phenomena that occur on the spatial scale of a classroom and on short time scales. They model how they can see objects within a room (6.1) and how objects (such as cups of liquid) cool off or warm up to reach room temperature (6.2). The models use behavior at the micro scale (particle interactions) to explain observable interactions (a cup sitting on a table in the classroom).

   Then, there is a shift in complexity of the phenomena being modeled in unit 6.3. The models move to different spatial and time scales. In their weather models, students model phenomena that take place across hundreds of miles, and across days, weeks or months. These models are also modeling behavior simultaneously at multiple levels. Students model interactions of air masses and interactions that occur within the air mass at the particle level. Technically, these practice elements are not novel in 6.3 as defined in NGSS Appendix F. This unit involves two elements that were also present in 6.1 and 6.2: *Develop and/or use a model to predict and/or describe phenomena* (SEP 2.5) and *Develop a model to describe unobservable mechanisms* (SEP 2.6). But more importantly, this modeling is very different from the students' perspective. It is very different to think through a process that occurs at the scale of atmospheric phenomena than what students did in the two prior units. And again it is different to model processes that occur at a very different time scale, across millennia, when students model causes of earthquakes in 6.4. So we tag units 6.3 and 6.4 as supporting further development of the modeling practice, rather than just providing a Key Use of the practice.

3. ***Explicit teaching to support the SEP or CCC:*** Units that Intentionally Develop an SEP or CCC contain explicit teaching about the parts of the SEP or CCC that are new, and contain scaffolding to support students' use. For example, unit 6.1 Intentionally Develops the *Asking Questions and Identifying Problems* practice, since this is the first time students develop researchable questions to post on the Driving Question Board in the OpenSciEd program. As part of the support for that practice, the teacher discusses open-ended versus closed-ended questions with students as part

of the preparation for asking students to generate questions to collect on the classroom's Drifting Question Board. The unit also contains a scaffolded question asking tool that helps students turn a close-ended question into an open-ended one (e.g., *how*, *why*, and *what happens if* questions) that can lead to investigation of phenomena.

4. ***Assessment guidance for the SEP or CCC:*** Units that intentionally develop an SEP or CCC typically provide assessment guidance for that SEP or CCC to help teachers assess students' development and provide feedback. These resources can be found in assessment tasks, assessment tools, *Assessment Opportunity* call-outs in lessons, and in the unit list of *Lesson-by-Lesson Assessment Opportunities* at the end of the teacher guide.

5. ***Use of the SEP or CCC in Lesson-Level Performance Expectations*****:** Units that intentionally develop an SEP or CCC will typically include that SEP or CCC in multiple lesson-level performance expectations. Lesson-level Performance Expectations can be found in each lesson in the *What Students Will Do* section on the first page of each lesson, and in the unit list of *Lesson-by-Lesson Assessment Opportunities* at the end of the teacher guide.

(B) The Unit Provides a *Key Use* of the SEP or CCC

Definition: In contrast to Intentionally Developed, units that provide a Key Use of an SEP or CCC ask students to use that SEP or CCC in ways that are not dramatically different in terms of the elements they draw on or the contexts in which they used it in earlier units. However, we consider the unit to be providing a Key Use of the SEP or CCC if that practice or concept plays a central role in the work students do in the unit. Thus, the unit provides a key opportunity for students to "practice" and deepen their experience working with the SEP or CCC.

Why is this important? Although SEPs and CCCs marked as Key Use in a unit are not new to students, the importance of their use in terms of student understanding of the phenomena and DCI learning should inform teacher planning. These label practices and concepts that play a key role in the work students do in the unit, drawing on what students have developed in prior units. Therefore, these are areas where teachers may want to focus their support for learning in this unit based on their students' successes and challenges in prior use of these practices or concepts. In addition, if the order of the units has been changed such that the instances where this practice or concept was developed has not yet happened, these Key Use labels identify opportunities to develop that SEP or CCC for the first time. That is, since the SEP or CCC plays a key role in the work of the unit, it would be meaningful to build in whatever supports and explicit teaching about the SEP or CCC that are in the earlier unit designed to introduce and develop them.

A unit that provides a Key Use of a particular SEP or CCC includes the following characteristics that make that SEP or CCC key to the sensemaking students do in the unit:

- ***Centrality to making sense of phenomena or solving problems:*** Because the three dimensions of NGSS work together, the use of an SEP or CCC is often central in the work of developing and using DCIs. In units where an SEP or CCC is defined as Key Use, that practice or concept plays a central role in the work students do. For example, Unit 7.1 provides a Key Use of the CCC *Patterns*. In this unit, students are trying to explain how particle level interactions can explain the appearance of gas bubbles from when a solid (the bath bomb) and a liquid (water) combine. In this work, students look for patterns of macroscopic occurrences in the bath bomb phenomena to figure the parrticle level interactions that can explain the phenomena (CCC 1.1). Students need to draw on their understanding from 6th grade units about how to use Patterns in data to develop their arguments, explanations, and model ideas. In this way, the CCC is *key to the sensemaking* that students do in the unit. But this central use of the CCC or SEP draws on aspects of using that concept or practice that should be familiar to students.

- ***Familiarity:*** In contrast to Intentionally Developing, the Key Use SEP or CCC itself is not one of the new things students are learning. The unit does not include new elements or explicit teaching about the SEP or CCC. Instead, they are engaging with the SEP or CCC in ways similar to uses in earlier units. Thus, it may be present in Lesson-Level Performance Expectations, because it is central in the task of the lesson, as in Intentionally Developed units, and the unit may contain assessment guidance on that practice or concept. But students should be *familiar with* rather than *developing* those aspects of the CCC or SEP that are called out for teachers in these ways. That distinction is important as teachers plan where their students may need more or less support in accomplishing the work of each lesson.

- ***Frequency:*** Because the SEP or CCC is central in making sense of phenomena or solving problems in the unit, it will often be drawn on in multiple lessons across the unit. (There are also a few cases where an SEP or CCC may play a very important role in the work students do in just one or two lessons.)

(C) The SEP or CCC is *Not a Focus* in the Unit

Definition: The CCC or SEP may be used in that unit, but it is not the direct focus of instruction or assessment. In contrast to units marked as Intentionally Developed, students are not building new aspects of the CCC or SEP. In contrast to units marked as Key Use, the SEP or CCC is not a central part of the work students do in the unit to make sense of phenomena or solve problems in the unit. However, due to the overlapping and complementary nature of the practices, there may be instances where students apply a CCC or SEP, but that will not be the focus of instruction or assessment.

For example, Unit 6.1 focuses on the practices of *Asking Questions and Identifying Problems*, *Developing and Using Models*, and *Constructing Explanations and Designing Solutions* as students investigate, ask questions to guide their investigations, and then develop models that can explain how and why various light phenomena occur. The practice *Using Mathematics and Computational Thinking* is indicated as Not A Focus in the unit. This does not mean that the use of this practice is completely absent. There may be one or a few instances (e.g., Lesson 3 in this unit) in which students work with and reason about data mathematically. But the practice is not the focus of the work students do in that lesson, and so the lesson does not provide instruction or assessment related to that practice.

Appendix C: SEP Progressions - A Detailed Look

In this Appendix, we consider each SEP and describe how students build the elements of the SEP across the program. We use the SEP elements as defined in NGSS Appendix F, and for ease of reference, we have numbered them. The following tables present the elements of each SEP followed by a table showing the progression of the SEP in grade 6, 7, and 8.

SEP1: Asking Questions and Identifying Problems

SEP1 NGSS: The Elements of *Asking Questions and Identifying Problems* in NGSS

SEP Elem	Description of Element of *Asking Questions and Identifying Problems*
	Ask questions...
1.1	... that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
1.2	... to identify and/or clarify evidence and/or the premise(s) of an argument.
1.3	... to determine relationships between independent and dependent variables and relationships in models.
1.4	... to clarify and/or refine a model, an explanation, or an engineering problem.
1.5	... that require sufficient and appropriate empirical evidence to answer.
1.6	... that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.
1.7	... that challenge the premise(s) of an argument or the interpretation of a data set.
1.8	Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

SEP1 G6: Progression for Asking Questions and Identifying Problems in Grade 6

Unit	Support for Growth in Asking Questions and Identifying Problems
6.1 Light and Matter	**Intentionally Developed:** Students begin the asking question process in the anchoring phenomenon lesson, drawing questions from their observations of phenomena (SEP 1.1) to develop the Driving Question Board (DQB). Students ask "what happens if" questions to guide initial investigations with their box models, and then co-construct an experimental, testable question to guide a controlled investigation (SEP 1.6). Throughout the unit, students continue to develop "how" and "why" questions to guide investigations and explain phenomena (SEP 1.3, 1.4).
6.2 Thermal Energy **6.3 Weather, Climate & Water Cycling** **6.4 Plate Tectonics & Rock Cycling**	**Key Use:** Asking questions and defining problems is central to the work of each of these units. Students ask questions and identify problems to develop the DQB at the beginning of the unit. The class then uses these DQB questions in the navigation work of each lesson to identify what question they need to work on. They use them again at the end of each lesson to figure out if there are new questions that need to be added to the DQB, and what questions they need to ask next to make progress. (SEP 1.1, 1.4, 1.6)
6.5 National Hazards	**Key Use:** Students identify criteria and constraints across different design aspects a of hazard response system: (1) structural design solutions to reduce damage, (2) technologies to detect and send warning signals and communication, and (3) communication and education plans that target stakeholders in the communities that will be impacted by a natural hazard (SEP 1.8).
6.6 Cells & Development	**Key Use:** Asking questions and defining problems is central in identifying what students need to figure out about healing and apply their ideas (SEP 1.1, 1.8).

SEP1 G7: Progression for Asking Questions and Identifying Problems in Grade 7

Unit	Support for growth in Asking Questions and Identifying Problems
7.1 Chemical Reactions & Matter	**Key Use:** Students develop questions to hep them figure out where the gas comes from that appears in the bath bomb phenomenon (SEP 1.1), identifying potential relationships between independent and dependent variables (SEP 1.3), and refining questions so that they can be conducted in the scope of the classroom (SEP 1.6). As their investigation proceeds, students develop new questions from their findings that lead to developing a mechanism for chemical reactions.
7.2 Chemical Reactions & Energy	**Intentionally Developed:**. Students define a design problem that can be solved through the development of a flameless heater (SEP 1.1) that includes consideration of multiple criteria and constraints. As students learn more about chemical reactions that transfer energy, they refine their criteria and constraints and revise their designs (SEP 1.4, 1.8).

<table>
<tr><th>Unit</th><th>Support for growth in Asking Questions and Identifying Problems</th></tr>
<tr><td>7.3 Metabolic Reactions</td><td rowspan="2">Key Use: Asking questions and defining problems continues to be central to the work of these units. As in prior units, students ask questions to develop the DQB at the beginning of the unit. The class uses these DQB questions in the navigation work of each lesson to identify what question they need to work on. They refer to their questions at the end of each lesson to figure out if there are new questions that need to be added to the DQB, and what questions they need to address next to make progress on their explanations. (SEP 1.1, 1.4)</td></tr>
<tr><td>7.4 Matter Cycling & Photosynthesis</td></tr>
<tr><td>7.5 Ecosystem Dynamics & Biodiversity</td><td>Intentionally Developed: This unit is anchored by a complex socioscientific issue. Students' initial questions lead them to investigate simple fixes to a complex problem (SEP 1.1, 1.6). The first lesson set serves to complicate the problem, helping students to define the problem in more detail and address it in later lessons. As in earlier units, students define a design problem that can be solved through the development of a system (SEP 1.4), but here their focus is designing a system that is limited by both scientific and social factors (SEP 1.8).</td></tr>
<tr><td>7.6 Earth's Resources & Human Impact</td><td>Intentionally Developed: Students engage in this practice in substantial ways by asking questions and defining problems related to a complex socio-scientific issue (SEP 1.1). While students have had experience with aspects of this practice in previous units, this unit engages students in asking questions that require sufficient and empirical evidence to answer (SEP 1.5) and asking questions to challenge arguments as they critique explanations of the case site communities and climate resilience design solutions (SEP 1.2, 1.7).</td></tr>
</table>

SEP1 G8: Progression for Asking Questions and Identifying Problems in Grade 8

<table>
<tr><th>Unit</th><th>Support for growth in Asking Questions and Identifying Problems</th></tr>
<tr><td>8.1 Contact Forces</td><td>Key Use: Asking questions and defining problems is central in the DQB and in navigation between lessons to guide students' sensemaking about forces (SEP 1.1, 1.3) and design to reduce damage to objects in collisions (SEP 1.8).</td></tr>
<tr><td>8.2 Sound Waves</td><td>Not A Focus</td></tr>
<tr><td>8.3 Forces at a Distance</td><td>Intentionally Developed: The unit introduces sentence frames to help students ask investigable questions about specific cause and effect relationships, and to construct scientific hypotheses from these questions that include a mechanistic account of an observable relationship between variables (SEP 1.3, 1.4, 1.5)</td></tr>
<tr><td>8.4 Earth in Space</td><td>Not a Focus</td></tr>
<tr><td>8.5 Genetics</td><td rowspan="2">Key Use: As in earlier units, students' questions are central in guiding investigations and identifying where sensemaking needs to go next to make progress on explanations and models (SEP 1.1, 1.2, 1.4, 1.5)</td></tr>
<tr><td>8.6 Natural Selection & Common Ancestry</td></tr>
</table>

SEP2: Developing and Using Models

SEP2 NGSS: The Elements of the SEP Developing and Using Models in NGSS

SEP Elem	Description of Element
2.1	Evaluate limitations of a model for a proposed object or tool.
2.2	Develop or modify a model — based on evidence — to match what happens if a variable or component of a system is changed.
2.3	Use and/or develop a model of simple systems with uncertain and less predictable factors.
2.4	Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
2.5	Develop and/or use a model to predict and/or describe phenomena.
2.6	Develop a model to describe unobservable mechanisms.
2.7	Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

SEP2 G6 Progression for Developing and Using Models in Grade 6

Unit	Support for growth in Developing and Using Models
6.1 Light and Matter	**Intentionally Developed:** This first unit in the program includes an explicit focus on modeling with modeling templates provided as scaffolds for students. In the first lesson, students explicitly discuss how to use physical models to test ideas about a phenomenon (SEP 2.7, the box model) and how to use diagrammatic models to represent and explain the phenomenon (SEP 2.5). Students build on understandings they bring from grades 3-5 about the limitations of models when they contrast the real-world system they are trying to understand (i.e., two rooms in the video) with their box models.. In subsequent lessons, students develop elements of the modeling practice for middle school as they discuss representation choices for diagrammatic models,model parts of the system at unobservable scales (SEP 2.6), include observable mechanisms that explain observable phenomena (SEP 2.4, e.g., light reflecting off microscopic, half-silvered, one-way mirror film), and modify a model to match if a variable is changed (SEP 2.2, e.g., changing the light conditions or swapping the one-way mirror for glass).

Unit	Support for growth in Developing and Using Models
6.2 Thermal Energy	**Intentionally Developed:** This unit provides explicit instruction and scaffolds to support students in modeling particle-scale mechanisms that result in observable heating and cooling phenomena (SEP 2.5). These include modeling templates, physical manipulatives (e.g., chips, marbles), and computer simulations. Students continue to develop models for explaining how unobservable mechanisms result in observable phenomena (SEP 2.6), but do so at the particle scale, which is a very different context than the macro scale encountered in Unit 6.1. Because of particle-scale mechanisms, simulations are necessary to support students in modeling relationships among variables (SEP 2.4). Students also develop models to plan for the cup design challenge, and to explain how their cup designs work to minimize energy transfer.
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** Students focus on a new element of modeling in evaluating the limitations of a model (SEP 2.1) in multiple lessons. Throughout this unit students develop and use models to explain phenomena (SEP 2.5) that build on, but are much more complex than, their prior work in Unit 6.2. The models students develop in this unit explain multiple energy transfer processes (radiation, conduction, convection) and multiple matter transformation processes (evaporation, condensation, and crystallization). Furthermore, these processes occur across different spatial scales and students connect them together to make sense of many weather- and climate-related phenomena. Students use models to describe interactions at the particle level as well as air parcels over a few miles, air masses over hundreds of miles, and prevailing systems over hemispheres.
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed:** While students have engaged with the elements of this practice in earlier units, they apply these elements in models at a much larger temporal and spatial scale than before. In Unit 6.2, students develop particle level models of a concrete phenomenon they can manipulate, and then in Unit 6.3 they continue to develop this practice in a larger context that is unobservable both at a micro and macro scale.. In this unit, students further develop this practice as they develop, revise, and use models multiple times over the course of the unit to explain the causal relationship between plate movement, erosion forces and changes to the surface of Earth. Students' models become more sophisticated as they continue to collect evidence supporting causal changes to Earth and describe phenomena happening over millions of years and across continents. (SEP 2.5, 2.6)
6.5 National Hazards	**Key Use:** Students continue to use models to explain a variety of phenomena at different scales (SEP 2.7). This unit emphasizes an important aspect of evaluating limitations of models (SEP 2.1) students compare three different ways to investigate how tsunamis form and move. They use a physical model, a visualization of the 2011 Japan tsunami, and a computerized simulation of a tsunami from a cross-section perspective and evaluate the benefits and limitations of each for understanding tsunamis, reinforcing this element introduced earlier in Unit 6.3.
6.6 Cells & Development	**Intentionally Developed:** While students engage in aspects of modeling they have used in prior units (SEP 2.5), this unit develops this practice in a very different context. This is the first biological system that students investigate in the program, and is their first experience tying physical mechanisms to phenomena that occur in living things. Beginning in the first lesson students develop a model for healing which they revise throughout the unit. The class develops a model of the structure and function of the different parts of the body and then apply what

Unit	Support for growth in Developing and Using Models
	they have figured out to develop a model for how skin heals from a scrape at the cellular level. In later lessons, students continue to revise their entire healing model to include what is happening at the cellular level and how systems interact, and finally use their elaborated model to explain how the body heals from an injury.

SEP2 G7: Progression for Developing and Using Models in Grade 7

Unit	Support for growth in Developing and Using Models
7.1 Chemical Reactions & Matter	**Key Use:** Over the course of the unit, students develop many models to explain phenomena (SEP 2.5). Two of these models are revisited and refined multiple times across lessons (the initial consensus model and a particle based model that is first introduced mid-unit). Students build on their experience with the practice from the 6th grade units 6.2 and 6.3 as they develop models at the microscopic scale to explain what is observable at the macroscale when a chemical reaction occurs (SEP 2.6). Students have frequent opportunities to develop models with a partner, in small groups, or as a class when they are making sense of new science ideas.
7.2 Chemical Reactions & Energy	**Key Use:** Students develop a model to track the flow of energy between parts of a system (SEP 2.6) and map this energy transfer model to elements of their design solutions (SEP 2.4). Based on that mapping, students use evidence from prototype testing to make decisions about their designs (SEP 2.2, 2.5).
7.3 Metabolic Reactions	**Key Use:** (SEP 2.1, 2.4, 2.5 2.7)
7.4 Matter Cycling & Photosynthesis	**Intentionally Developed:** Over the course of the unit, students incrementally develop a system model of the carbon cycle down to the atomic level to represent the movement of matter and energy through the environment when plants make food. This is the first time in the program that students model phenomena to explain interactions (SEP 2.4, 2.5) of both living and nonliving systems together. The unit supports students in this work by incrementally developing this model across many lessons. Students begin by developing an initial model to represent what the plant needs to make food molecules. Later, students have figured out that plant cells contain special structures (chloroplasts) that allow the plant to obtain sunlight for energy to convert carbon dioxide and water into sugar (a food for the plant) that provides a form of energy for the plant. At the completion of the unit, students have extended their models to include the movement of molecules/atoms between producers, consumers and decomposers.
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students focus on constructing system models for different agricultural systems and natural ecosystems. They use these models to predict how disruptions impact populations and humans in the system. Students also use a computer model to generate data to test ideas about population dynamics in the rainforest and farm designs (SEP 2.4, 2.5). They

Unit	Support for growth in Developing and Using Models
	evaluate the limitations of the computer model in comparison to the complex real-world systems the model is representing (SEP 2.1).
7.6 Earth's Resources & Human Impact	**Key Use:** Students' draw on previous models and model ideas developed in the context of macro scale systems they worked on in Units 6.3, 7.3, and 7.4 to represent global water cycling and carbon cycling systems. They use these large-scale system models to make predictions and test ideas (SEP 2.2, 2.5, 2.6, 2.7).

SEP2 G8: Progression for Developing and Using Models in Grade 8

Unit	Support for growth in Developing and Using Models
8.1 Contact Forces	**Key Use:** (SEP 2.2, 2.4, 2.5, 2.6, 2.7)
8.2 Sound Waves	**Key Use:** Students develop models to make sense of and explain almost every aspect of what they figure out about what makes sound, how it travels, and how we perceive it (SEP 2.2, 2.4, 2.5). Students have frequent opportunities to develop and revise models with a partner, in small groups, or as a class. Students' models include particle-level interactions (unobservable mechanisms) that explain how vibrating matter makes sound, how sound travels through a medium, and how sound can be detected (SEP 2.6).
8.3 Forces at a Distance	**Key Use**: Students develop and use models throughout the unit to try to explain how some parts of the speaker are moving without being in contact with the rest of the system (SEP 2.6, 2.7). They use their models to test cause and effect relationships to describe how the speaker works (SEP 2.2, 2.3, 2.4).
8.4 Earth in Space	**Intentionally Developed:** Although students have had much experience developing models to explain phenomena in earlier units (SEP 2.5), in this unit they develop and use models to explain phenomena at very different scales of time and space. For example, the forces between objects involve planetary size objects and the distances are very different from the distances students have reasoned about in prior units. Students also need to use these models to engage in difficult spatial reasoning to explain phenomena such as lunar phases and eclipses. Students develop, use, and revise models from the start and throughout the unit to explain patterns in the sky ranging from why Manhattahenge occurs twice a year in the same spot, why the seasons in Australia are opposite of seasons in the Northern Hemisphere, why the Moon appears redder during a lunar eclipse but does not go completely dark, why planets go around the Sun and moons go around planets, our place in the solar system and galaxy (SEP 2.2, 2.4, 2.5, 2.6).

Unit	Support for growth in Developing and Using Models
8.5 Genetics	**Key Use:** Students use models to make sense of and explain almost every aspect of what they figure out in this unit (SEP 2.5). Students have frequent opportunities to develop models with a partner, in small groups, or as a class when they are making sense of new science ideas. Students then use models independently to explain those science ideas and relationships on assessments at three key moments at midpoints and the end of the unit. These models of these complex phenomena represent multiple cause-and-effect relationships at multiple scales (SEP 2.4, 2.6).
8.6 Natural Selection & Common Ancestry	**Key Use:** (SEP 2.3, 2.5, 2.6)

SEP3: Planning & Carrying Out Investigations

SEP3 NGSS: The elements of Planning and Carrying Out Investigations in NGSS

SEP Elem	Description of Element
3.1	Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
3.2	Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
3.3	Evaluate the accuracy of various methods for collecting data.
3.4	Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
3.5	Collect data about the performance of a proposed object, tool, process or system under a range of conditions

SEP3 G6: Progression for Planning and Carrying Out Investigations in Grade 6

Unit	Support for growth in Planning and Carrying Out Investigations
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Intentionally Developed:** Students explore initial questions they have about cups through uncontrolled investigations, and then through a series of highly controlled investigations,

Unit	Support for growth in Planning and Carrying Out Investigations
	to come to the conclusion that matter is not moving between systems, but rather energy is transferring between systems. Students articulate independent, dependent, and control variables; they co-construct collaborative investigation procedures to follow, reflect on ways to minimize error in their procedures, and fine tune procedures (SEP 3.1, 3.3). In the design challenge, students define procedures to conduct fair tests under a range of conditions, and revisit those procedures to fine tune them before they conduct tests on their optimized designs (SEP 3.4, 3.5).
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** In the first half of the unit, students conduct investigations in five different lessons that help them develop a model of cause and effect relationships involved in the energy transfer processes (radiation, conduction, convection) and matter transformation processes (evaporation, condensation, and crystallization) that cause weather phenomena (SEP 3.1, 3.4). Students also engage in a new element of this practice (SEP 3.2) as they evaluate and revise various aspects of their investigation designs, including data collection protocols, a simulation interface, and the experimental design.
6.4 Plate Tectonics & Rock Cycling	**Not a Focus**
6.5 National Hazards	
6.6 Cells & Development	**Key Use:** Students plan and carry out investigations across multiple lessons to help figure out how healing occurs (SEP 3.2, 3.4). Students observe a chicken wing dissection and then brainstorm how they would revise this dissection to “injure” the chicken wing in a similar manner to the injury sustained by the student in the anchoring phenomenon. Students also carry out an investigation using microscopes to look at a blood sample and then plan for an investigation that could provide evidence as to whether other things in our world are made of cells. Toward the end of the unit, students carry out an investigation to figure out if things like food particles can get into an onion cell.

SEP3 G7: Progression for Planning and Carrying Out Investigations in Grade 7

Unit	Support for growth in Planning and Carrying Out Investigations
7.1 Chemical Reactions & Matter	**Intentionally Developed:** While students have had experience in multiple 6th grade units with aspects of this practice, working as a class and in small groups, in this unit students deepen their use of the practice so that they can engage in a full design for investigations as individuals, and are assessed on this practice. In the first lesson set, students co-design two investigations with the whole class to determine where the gas is coming from when a bath bomb is placed in water, and design and carry out an investigation in a small group to determine what combinations of bath bomb ingredients leads to a gas forming (SEP 3.2, 3.4). Students continue to engage with this practice through the second half of the unit either with the whole class or in small groups. The

Unit	Support for growth in Planning and Carrying Out Investigations
	final assessment includes them individually planning and carrying out an investigation on pieces of marble (calcium carbonate) to figure out why the surface of the marble on the Taj Mahal is crumbling, and propose other investigations that could to collect additional evidence to help them more fully explain what is happening to the Taj Mahal (SEP 3.1., 3.2, 3.4).
7.2 Chemical Reactions & Energy	**Key Use:** Students figure out what kind of data they need to collect to test their hypothesis that a chemical reaction is occurring in their flameless heaters. They perform investigations, collect data, and interpret the results to figure out that energy is transferred during a chemical reaction (SEP 3.2). Students use data they collect about energy transfer during several different chemical reactions under different conditions (proportion of reactants, amount of reactants and amount of food heated) to help them design their initial prototypes. Students evaluate the investigation procedure and the data collection methods to identify ways to improve the accuracy of data collection, and revise their methods for temperature data collection and qualitative observations of the products. As students test their designs, they collect data about the performance of the heater under a range of conditions (i.e. with different groups attempting to follow the instructions they designed), and use that evidence to inform redesign (SEP 3.4).
7.3 Metabolic Reactions	**Key Use:** (SEP 3.2, 3.4)
7.4 Matter Cycling & Photosynthesis	**Key Use:** (SEP 3.1, 3.2, 3.4)
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students carry out a series of investigations in a computer simulation to produce data about how orangutans compete with each other for food resources in different environmental conditions, and collect data from an investigation to figure out how stable populations of orangutans fluctuate over time based on resource availability. At the end of the unit, students use the simulation to collect data and produce data about design solutions and proposed systems under a range of conditions (SEP 3.4)
7.6 Earth's Resources & Human Impact	**Not a Focus**

SEP3 G8: Progression for Planning and Carrying Out Investigations in Grade 8

Unit	Support for growth in Planning and Carrying Out Investigations
8.1 Contact Forces	**Key Use:** (SEP 3.2, 3.4)
8.2 Sound Waves	**Not a Focus**

Unit	Support for growth in Planning and Carrying Out Investigations
8.3 Forces at a Distance	**Intentionally Developed:** Students use hypothesis-building cause-effect sentence frames to identify variables they need to test to evaluate their hypothesis (SEP 3.1). In the last part of the unit, students plan and conduct an investigation collaboratively as a class and in small groups to produce data to serve as the basis for evidence for describing cause and effect relationships between factors in a speaker system (SEP 3.2, 3.4).
8.4 Earth in Space	**Key Use:** (SEP 3.4)
8.5 Genetics	**Key Use:** (SEP 3.2, 3.4)
8.6 Natural Selection & Common Ancestry	**Key Use:** (SEP 3.2, 3.4)

SEP4: Analyzing and Interpreting Data

SEP4 NGSS: The Elements of Analyzing and Interpreting Data in NGSS

SEP Elem	Description of Element
4.1	Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
4.2	Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
4.3	Distinguish between causal and correlational relationships in data.
4.4	Analyze and interpret data to provide evidence for phenomena.
4.5	Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.
4.6	Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
4.7	Analyze and interpret data to determine similarities and differences in findings.
4.8	Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

SEP4 G6: Progression for Analyzing and Interpreting Data in Grade 6

Unit	Support for Growth in Analyzing and Interpreting Data
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Intentionally Developed:** Students work with data throughout this unit as they conduct investigations and use data as evidence for their claims about relationships between factors (SEP 4.2) that explain phenomena and inform their designs (SEP 4.4, 4.7). Students calculate means from pooled data across the class (SEP 4.5). They consider limitations of data analysis given the accuracy of the digital scale (+/- 0.1 g) and discuss how averaging multiple measurements from many trials can help counterbalance this source of error (SEP 4.6). They also use their data to modify their data collection methods to work toward more precise data collection.
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** This unit is students' first exposure to working with large data sets, and they will do more complex numerical analysis than in prior units and use new types of data representations, including maps at multiple temporal and spatial scales and with multiple types of data overlays (SEP 4.2). The structure of these data grows in complexity as the unit progresses. For example, students analyze hail accumulation maps from multiple cities at the beginning of the unit and later analyze two parallel sets of global maps (net radiation and land surface temperature) from two different times of year (SEP 4.7). Then by the end of the unit, students analyze a time series set of national weather maps with multiple layers of overlaid data, including precipitation amounts and types, cloud cover, low pressure air mass centers, and fronts (SEP 4.4).
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed**: Students' work in this unit focuses on a new aspect of analyzing data to distinguish causal from correlational relationships in data (SEP 4.3). Throughout the unit students investigate different potential causes for changes to Earth's surface that happen below and above the surface (SEP 4.2). They differentiate between causation and correlation and draw on these data interpretations in their models and arguments.
6.5 National Hazards	**Key Use:** Students construct and/or use multiple graphical displays (e.g., maps, scatter plots) of large data sets to identify linear relationships and distinguish between correlation and causation (SEP 4.2, 4.3, 4.4).
6.6 Cells & Development	**Intentionally Developed:** While students have engaged with this practice in earlier units, in this unit students analyze different kinds of data (including images at different scales) in a new context: living things. Students identify the macro-level functions of skin, bone, and muscle, and figure out that the microscopic structures (cells) in blood and nerves support the functions of those body parts. Students analyze and interpret observational data, videos, and images to provide evidence that cell growth occurs. Students analyze second-hand data from an investigation of *E.coli* to collect evidence that the bacteria need

Unit	Support for Growth in Analyzing and Interpreting Data
	food to make more cells and the more food the bacteria are provided, the more the bacteria make more cells. (SEP 4.4, 4.7)

SEP4 G7: Progression for Analyzing and Interpreting Data in Grade 7

Unit	Support for Growth in Analyzing and Interpreting Data
7.1 Chemical Reactions & Matter	**Intentionally Developed:** While students have analyzed and interpreted data through many of the sixth grade units, in this unit students take on increasing responsibility for figuring out what data they need, how to collect it, and how to represent and analyze it (SEP 4.4, 4.7). Students begin their work with this practice at the start of the unit when they argue in small groups and as a class for what data they need to collect and how they can record it to be able to do the analyses they need for their questions. In Lesson 3 they analyze their first property data table. As the unit progresses, students construct and analyze data tables to help them figure out different parts of the story of what is happening when the bath bomb is placed in water. They collect data to determine the substances in the bath bomb that cause the gas (Lesson 4), record data from flammability and density tests of gases and use a property data table to determine what gas could be produced (Lesson 5), and argue for what additional data they need to analyze (Lesson 7). Students analyze and interpret their data to provide evidence for phenomena as they analyze data to determine whether a chemical reaction has occurred in several new scenarios and argue for what additional data they would need to be more confident in their explanations.
7.2 Chemical Reactions & Energy	**Intentionally Developed:** Students analyze data to define an optimal operational range for a flameless heater that best meets criteria for success (SEP 4.8). Students use a matrix to track how well their prototypes meet the criteria and constraints developed and further analyze the effects of design changes with regard to device performance, but also different impacts on various stakeholders).
7.3 Metabolic Reactions	**Intentionally Developed:** Students work with a new element of this practice when they construct and analyze a graphical display of the relationship between height of the villi in the small intestine and the number of cells present as part of their investigations of metabolic reactions (SEP 4.1). Students use this graphical display to understand why the rate of absorption of food molecules increases as villi height increases. Throughout the unit, students use the I^2 sensemaking strategy to support the use of analyzing various data sets. In early lessons students analyze a multivariable data set showing the average percentage of breakdown of food molecules of a graham cracker as it passes through the digestive system in a healthy person vs. M'Kenna. Students then explore whether the patterns they observe with changes in food molecules in the mouth are causal or correlational and determine that an experiment is needed to collect more data in order to make causal claims. This practice is formatively assessed in multiple lessons.

Unit	Support for Growth in Analyzing and Interpreting Data
7.4 Matter Cycling & Photosynthesis	**Not a Focus**
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students analyze populations over time as represented with line graphs and histograms to identify natural fluctuations versus long-term populations trends. Their focus is to identify temporal relationships in populations and resource availability (SEP 4.2, 4.5).
7.6 Earth's Resources & Human Impact	**Key Use:** Students analyze precipitation and temperature data over time using line graphs to identify natural fluctuations versus long-term trends, reinforcing these ideas from earlier units in a new context (SEP 4.2, 4.4, 4.5, 4.7).

SEP4 G8: Progression for Analyzing and Interpreting Data in Grade 8

Unit	Support for growth in Analyzing and Interpreting Data
8.1 Contact Forces	**Intentionally Developed:** Students work a new kind of mathematical relationship in their data analysis. Students construct, analyze, and interpret graphical displays to identify linear and nonlinear relationships and determine that the kinetic energy of a moving object is proportional to its mass and its kinetic energy is related to the square of its speed (SEP 4.1, 4.4). Students also find lines of best fit and identify quantitative relationships in their data related to the amount of deformation per Newton of force and the change in Kinetic Energy as a scale factor.
8.2 Sound Waves	**Key Use:** (SEP 4.1, 4.4, 4.5)
8.3 Forces at a Distance	**Key Use:** Students analyze data from their investigations in order to identify and describe the nonlinear relationships between various factors and magnetic force (SEP 4.1, 4.2)
8.4 Earth in Space	**Intentionally Developed:** Students use of this practice in the context of space systems involves very different kinds of data to analyze and represent. Students use multiple graphical displays (e.g., maps, scatter plots) of large data sets (SEP 4.2) to identify and explain patterns in sky (such as solar elevation, length of day, location and paths of motion for objects in the sky, and the organization of the solar system (SEP 4.4).
8.5 Genetics	**Not a Focus**
8.6 Natural Selection & Common Ancestry	**Intentionally Developed:** Students investigate large data sets for variations in animals' body structures and changes over time (SEP 4.1, 4.3). Although students have had prior experience with this practice, the data sets they use in this unit are the largest and most complex that they have worked with in the program. Throughout the unit, students analyze and interpret data from photos, sketches, modern and ancient world maps, organism size comparison charts, timelines, tables displaying multiple categories of body structure, environmental and behavioral information, linear models, histograms, and

Unit	Support for growth in Analyzing and Interpreting Data
	box-and-whisker plots. Students consider the role of randomness in the simulation they use to describe the shifts in distribution and central tendency of traits in populations (SEP 4.5). The work of this unit requires students to synthesize these data sets in more complex ways than they did in past units. Students combine evidence from their analyses and interpretation of data about multiple organisms to support the models they develop throughout the unit (SEP 4.7). The unit provides several different opportunities to assess students' work in this practice.

SEP5: Using Mathematics and Computational Thinking

SEP5 NGSS: The Elements of Using Mathematics and Computational Thinking in NGSS

SEP Elem	Description of Element
5.1	Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
5.2	Use mathematical representations to describe and/or support scientific conclusions and design solutions.
5.3	Create algorithms (a series of ordered steps) to solve a problem.
5.4	Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
5.5	Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.

SEP5 G6: Using Mathematics and Computational Thinking in Grade 6

Unit	Support for Growth in Using Mathematics and Computational Thinking
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	
6.3 Weather, Climate & Water Cycling	**Key Use:** In their work to analyze large data sets, students apply mathematical concepts and processes to scientific questions (SEP 5.4) and use mathematical representations to describe and support scientific conclusions (SEP 5.2).
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed:** Students engage with mathematical reasoning as they grapple with what Earth looked like in the past. Using rate of plate movement, students determine where the continents could have been in the past (SEP 5.4). Students also engage in a new

Unit	Support for Growth in Using Mathematics and Computational Thinking
	aspect of mathematical and computational thinking as they work with representations of very large data sets through computer interactives and mapped representations (SEP 5.1). To support this practice, aspects of the simulations are slowly added to allow students to make sense of the data being represented over the course of the unit.
6.5 National Hazards	**Intentionally Developed:** Students extend their use of this practice in a new way when they combine multiple digital tools to analyze maps and create scatterplots of large data sets (SEP 5.1). For the first time, students use digital tools and arguments to test and compare proposed solutions to their design problem (SEP 5.5). This work supports students in identifying patterns and trends between multiple variables and refining their hazard predictions (SEP 5.2).
6.6 Cells & Development	**Not a Focus**

SEP5 G7: Using Mathematics and Computational Thinking in Grade 7

Unit	Support for Growth in Using Mathematics and Computational Thinking
7.1 Chemical Reactions & Matter	**Not a Focus**
7.2 Chemical Reactions & Energy	
7.3 Metabolic Reactions	
7.4 Matter Cycling & Photosynthesis	
7.5 Ecosystem Dynamics & Biodiversity	**Intentionally Developed:** While students have applied other mathematical concepts to analyze phenomena in earlier units, here students calculate ratios of orangutans to land area to understand population density. They also characterize and use graphical representations of populations over time to draw conclusions about resource availability and population sizes (SEP 5.2). They use mathematical representations using graphs to support that stable populations experience ups and downs from year to year, which is different from a representation of an unstable population (SEP 5.4). Students are assessed on the practice in an problem involving Monarch butterflies at the midpoint of the unit (SEP 5.2, 5.4)

Unit	Support for Growth in Using Mathematics and Computational Thinking
7.6 Earth's Resources & Human Impact	**Intentionally Developed:** Students continue to develop and use mathematical concepts of rate and ratio reasoning to make sense of phenomena (SEP 5.4). In this unit, they extend this practice by using math to make sense of percent change in GHGs over time, proportional relationships between GHGs and temperature, rates of carbon fluxes that lead to imbalance, and rates of carbon offset that can solve the carbon imbalance (SEP 5.2, 5.4). They also engage in using digital tools to create and/or analyze graphs of data to determine trends and patterns over time (SEP 5.1). Finally, they use mathematical concepts to support their decisions about whether carbon solutions meet the class agreed-upon criteria and constraints to reduce the carbon imbalance.

SEP5 G8: Using Mathematics and Computational Thinking in Grade 8

Unit	Support for Growth in Using Mathematics and Computational Thinking
8.1 Contact Forces	**Not a Focus**
8.2 Sound Waves	**Intentionally Developed:** Lessons 4-6 involve students in novel uses of mathematical representations when they figure out how to develop and experiment with a scaled-up version of the phenomena so they can analyze non visible motions of objects making sound (SEP 5.2). They represent an object's motion graphically and use these mathematical representations of position versus time graphs generated from the movement of an object making louder/softer and higher/lower pitch sounds to describe wave patterns (frequency and amplitude) and to figure out how objects making different sounds move (SEP 5.4). In later lessons students analyze patterns in the rate of and spacing in between compression bands to characterize relationships between wavelength, frequency, and amplitude. They apply linear and nonlinear relationships to identify that the energy transferred does not increase in proportion to amplitude and that increasing amplitude increases energy transfer more than increasing frequency (SEP 5.4). If students have studied exponential relationships they can further characterize the non linear relationship in the graph for amplitude vs energy transferred as an exponential relationship. Students also have the opportunity to construct equations to describe the relationships between these variables in algebraic terms (i.e., energy is related to the amplitude squared).
8.3 Forces at a Distance	**Key Use:** Students analyze data from their investigations in order to identify and describe the nonlinear relationships between various factors and magnetic force (SEP 5.2, 5.4)
8.4 Earth in Space	**Not a Focus**
8.5 Genetics	**Intentionally Developed:** Students calculate the probability of offspring phenotypes from various parental crosses in multiple lessons (SEP 5.4). Later in the unit, students work with a new aspect of the practice as they develop the series of ordered steps as an algorithm (SEP 5.3). In addition, students use digital tools to analyze very large data sets for patterns and trends in Lesson 16 (SEP 5.1).

Unit	Support for Growth in Using Mathematics and Computational Thinking
8.6 Natural Selection & Common Ancestry	**Not a Focus**

SEP6: Constructing Explanations and Designing Solutions

SEP6 NGSS: The Elements of Constructing Explanations and Designing Solutions in NGSS

SEP Elem	Description of Element
6.1	Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
6.2	Construct an explanation using models or representations.
6.3	Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
6.4	Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6.5	Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
6.6	Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
6.7	Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
6.8	Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

SE6 G6: Constructing Explanations and Designing Solutions in Grade 6

Unit	Support for Growth in Constructing Explanations and Designing Solutions
6.1 Light and Matter	**Intentionally Developed:** This unit focuses on constructing written explanations. For the first time in the program, students develop a written explanation for the phenomenon (SEP 6.2). First, they collaboratively write an explanation to one of their questions, with the teacher modeling how to write an explanation supported by a how and why account and evidence. Then students independently write an explanation for a second question about

Unit	Support for Growth in Constructing Explanations and Designing Solutions
	the phenomena, receive feedback from the teacher and peers, and revise their explanations (SEP 6.4).
6.2 Thermal Energy	**Intentionally Developed:** Students use scientific ideas to construct and test an object that is designed to slow energy transfer (SEP 6.6). Students articulate precise criteria and constraints for the design challenge, and identify how to test the devices against those criteria and constraints (SEP 6.7). They undertake this design project with multiple design cycles in which students tweak design features to optimize their device's performance (SEP 6.8). Students explain how features of their device worked and why and which features did not work and why, connecting these back to the criteria and constraints agreed upon for the design challenge (SEP 6.4).
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** Students use a new element of this practice when they construct explanations including qualitative and quantitative relationships between variables to predict and describe phenomena (SEP 6.1). Students apply scientific ideas and principles to explain a very wide array of phenomena, including the formation of hail, the growth of clouds, some of the causes of precipitation and surface winds, the formation and strengthening of hurricanes, why fronts form and move the way they do, and why rainforests are sometimes located in some parts of the world but not in other areas nearby (SEP 6.2, 6.4). Both the complexity and scale (temporal and spatial) of the phenomena students explain in this unit extend what students have done in prior units.
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed:** As students carry out investigations and analyze data to collect evidence, they construct explanations to explain causal relationships between the processes they are investigating and changes to Earth's surface. Students work with a new idea, that theories and laws that describe the natural world operate today as they did in the past (SEP 6.3). Initially students construct explanations about relationships between earthquakes and mountains changing. Then they construct an explanation about relationships between plates moving and earthquakes and mountains moving. Eventually, at the end of the unit, students can explain the relationship between processes above and below the surface and how they shape Earth, and show how the evidence is adequate for their explanations (SEP 6.2, 6.4, 6.5).
6.5 National Hazards	**Key Use:** Students use a systematic process to evaluate different design solutions, technologies, and communication options and develop a representation of how all these components of subsystems work together in a complex hazard response system to protect communities (SEP 6.1, 6.4, 6.6, 6.8).
6.6 Cells & Development	**Key Use:** (SEP 6.4)

SEP6 G7: Constructing Explanations and Designing Solutions in Grade 7

Unit	Support for Growth in Constructing Explanations and Designing Solutions
7.1 Chemical Reactions & Matter	**Intentionally Developed:** Explanation and argument frequently work together in the unit. The unit contains support for teachers to guide students in more elaborated arguments and explanations, articulated both verbally and in writing, than in prior units. The unit supports students in incrementally assembling a multiple step argument, supporting each step with evience, for an explanation for what happens to the matter of the bath bomb in water (SEP 6.2, 6.4). As students collect new data, information, or evidence, they identify key model ideas (scientific principles) that they then use to construct arguments for their explanations of the various phenomena in the unit (bath bombs, elephant's toothpaste, electrolysis, or crumbling marble on the Taj Mahal, SEP 6.2, 6.4). The second half of the unit focuses on helping students use the scientific ideas, principles, and evidence they have assembled to construct a mechanistic causal explanation for how the matter rearranges to form new substances leading to the gas product of the bath bomb in water (SEP 6.1. 6.4). (See also SEP 7)
7.2 Chemical Reactions & Energy	**Key Use:** Students figure out that energy transfer happens during chemical reactions, and the type of substances reacting, and the amount and proportions of those substances, affect energy transfer. They apply these ideas to design, construct, and test a flameless heater system that can be used to heat food in an emergency (SEP 6.6, 6.7). They undertake this design project and engage in the design cycle to construct a homemade flameless heater and instructions for users that meet specific design criteria and constraints. Throughout the unit students work to optimize performance of their flameless heater by prioritizing criteria, making tradeoffs, testing, revising, and re-testing (SEP 6.8).
7.3 Metabolic Reactions	**Key Use:** (SEP 6.1, 6.2, 6.4)
7.4 Matter Cycling & Photosynthesis	**Key Use:** (SEP 6.4, 6.5)
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students apply science ideas to construct explanations for how approaches to agriculture work to support orangutans and people. Students apply science ideas to design land-use systems, and optimize these systems to both support orangutans and be financially viable for people. Students consider the benefits and trade-offs of different designs for stakeholders (SEP 6.6).
7.6 Earth's Resources & Human Impact	**Key Use:** Students develop and defend evidence-based explanations for the impact of temperature change (SEP 6.3) and engage in argumentation to support and critique them (See also SEP7). They draw on principles and evidence to develop and evaluate climate resilience plans (SEP 6.6).

SEP6 G8: Constructing Explanations and Designing Solutions in Grade 8

Unit	Support for Growth in Constructing Explanations and Designing Solutions
8.1 Contact Forces	**Key Use:** (SEP 6.1, 6.2, 6.4, 6.6, 6.8)
8.2 Sound Waves	**Not a Focus**
8.3 Forces at a Distance	**Key Use:** (SEP 6.4)
8.4 Earth in Space	**Not a Focus**
8.5 Genetics	**Key Use:** (SEP 6.2, 6.4)
8.6 Natural Selection & Common Ancestry	**Intentionally Developed:** Students construct explanations throughout the unit as they gather evidence for the mechanism in their general model for natural selection in effort to explain "Where did all the ancient penguins go?" and "Where did all the different species of modern penguins come from?" Students have experience with this SEP from prior units, including with long time scales and small changes accumulating over time, but now they are building that kind of explanation in living systems (SEP 6.1, 6.2, 6.3, 6.4). There are multiple opportunities to assess students' independent use of this practice throughout the unit, including a peer feedback activity in the last learning set during which students respectfully provide critiques about each other's explanations and respond by adding more elaboration and detail.

SEP7: Engaging in Argument from Evidence

SEP7 NGSS: The Elements of Engaging in Argument from Evidence in NGSS

SEP Elem	Description of Element
7.1	Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
7.2	Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
7.3	Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
7.4	Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.

SEP Elem	Description of Element
7.5	Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

SEP7 G6: Engaging in Argument from Evidence in Grade 6

Unit	Support for Growth in Engaging in Argument from Evidence
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Key Use:** Students develop an argument, using evidence from their investigation and personal experiences of condensation, to argue that water forming on the outside of the cup comes from the air as opposed to coming from inside the cup. Students also organize and use evidence to support claims that temperature changes are due to the movement of heat rather than cold between samples of matter. (SEP 7.3)
6.3 Weather, Climate & Water Cycling	**Not a Focus**
6.4 Plate Tectonics & Rock Cycling	**Key Use:** In the middle of the unit, students reason using evidence to construct two written arguments: in support of which model best explains how mountains increase in elevation and in support of how earthquakes happen. Later in the unit, students construct an argument regarding what is happening where two plates are moving apart, present their arguments to classmates, and together evaluate which claim(s) the evidence best supports. (SEP 7.3)
6.5 National Hazards	**Intentionally Developed:** For the first time in 6th grade students are evaluating competing design solutions based on jointly developed and agreed-upon design criteria (SEP 7.5). Initially students are given some criteria for the tsunami design solutions, but later in the unit, they develop their own jointly agreed-upon criteria for natural hazards communication systems. This scaffolding allows students to practice developing criteria and constraints as a class and then applying them to design solutions. Students also evaluate advertised devices that can reduce the impacts of a tsunami and discuss those potential solutions as a class based upon community criteria and constraints (SEP 7.4).
6.6 Cells & Development	**Key Use:** Students engage in argumentation many times throughout the unit as they explain what is happening in the body for it to heal. Students argue orally in support of which interactions between the bone and muscle and skin are needed for a part of the body to function. Students also argue from evidence for whether the living things they analyzed are made of cells or not, for what human cells need to grow and make more cells, and for what bacteria need to grow and make more of themselves. Finally, students argue from evidence for what caused the different healing events on the timeline of the student's foot healing and for whether the healing process is similar or different from the growth process and why (SEP 7.3).

SEP7 G7: Engaging in Argument from Evidence in Grade 7

Unit	Support for Growth in Engaging in Argument from Evidence
7.1 Chemical Reactions & Matter	**Intentionally Developed:** Explanation and argument work together in the unit. The unit contains support for teachers to guide students in more elaborated arguments and explanations, articulated both verbally and in writing, than in prior units. The first half of the unit supports students' in incrementally assembling a multiple step argument, supporting each step with evidence, for an explanation for what happens to the matter of the bath bomb in water (SEP 7.1, 7.3). As students collect new data, information, or evidence, they pause to record new key model ideas (scientific principles) that they then use to construct arguments for their explanations of the various phenomena in the unit (bath bombs, elephant's toothpaste, electrolysis, or crumbling marble on the Taj Mahal, SEP 7.1, 7.2, 7.3).
7.2 Chemical Reactions & Energy	**Key Use:** (SEP 7.2, 7.4, 7.5)
7.3 Metabolic Reactions	**Key Use:** Students construct, critique, and revise multiple arguments in multiple lessons across the unit for their conclusions from investigations to figure out what distinguishes the metabolic processes in M'Kenna's system that explains her symptoms (SEP 7.2, 7.3). Students use evidence from their investigations of starch and glucose in dialysis tubing experiments to argue for revisions of their models of the small intestine to explain how it enables the absorption of glucose (SEP 7.3). Later, in an assessment task, students use empirical evidence from multiple sources and scientific reasoning to rule out some gastrointestinal conditions as explanations of M'Kenna's symptoms. Students then create an argument for which diagnosis best explains M'Kenna's symptoms, compare and critique each other's arguments, and revise them based on these critiques (SEP 7.2). They revise these arguments in later lessons based on new evidence. Finally at the end of the unit, students work collaboratively to create an argument from evidence in order to determine if their chosen animal digests food the same way as humans, and revise these arguments based on feedback (SEP 7.2, 7.3).
7.4 Matter Cycling & Photosynthesis	**Key Use:** Students frequently construct arguments supported by empirical evidence and scientific reasoning. Two of these key arguments include (a) a written argument supported by evidence about whether hydroponic plant food solution and plain water could be the source of food molecules in plants; (b) an argument with evidence for students' explanations of how different inputs (carbon dioxide, light, and water) and plant components (chloroplasts) interact to make food (SEP 7.3). In constructing these arguments and those in later lessons, students support their arguments with evidence, compare and critique different claims (SEP 7.1, 7.2), and revise them based on peer feedback.
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students construct an argument with supporting evidence to explain cases involving disruptions in one part of the system that affect other populations in the system (SEP 7.3). Students also evaluate competing design solutions and construct an argument

Unit	Support for Growth in Engaging in Argument from Evidence
	grounded in evidence and scientific reasoning to recommend a design solution that can support a stable orangutan population and protect the needs of people (SEP 7.5).
7.6 Earth's Resources & Human Impact	**Key Use:** Students develop, support with evidence, and critique explanations about how changes in temperature are having impacts on the water stories in the case site communities and evaluate claims and evidence in a social media post (SEP 7.2, 7.3). At the end of the unit students evaluate competing design solutions in climate resilience plans based on agreed-upon design criteria (SEP 7.5).

SEP7 G8: Engaging in Argument from Evidence in Grade 8

Unit	Support for Growth in Engaging in Argument from Evidence
8.1 Contact Forces	**Key Use:** (SEP 7.1, 7.2, 7.3)
8.2 Sound Waves	**Key Use:** Students construct written and oral arguments throughout Lesson Sets 1 and 2. Students construct arguments from evidence about whether all objects vibrate when they make sounds; to support an explanation for which patterns of frequency and amplitude of a wave are related to sounds that we can hear; and whether matter is traveling all the way from the speaker to the window (SEP 7.3). They compare claims about whether air is needed for sound to travel to where we can hear it and use evidence from their investigations to select and defend one of these claims (SEP 7.1). Students critique their classmates' explanations and models and respond to those critiques by citing relevant evidence from their investigations and revising their explanations and models (SEP 7.2).
8.3 Forces at a Distance	**Not a Focus**
8.4 Earth in Space	
8.5 Genetics	
8.6 Natural Selection & Common Ancestry	**Key Use:** Arguing from evidence they have collected from multiple investigations is embedded in students' work across many lessons as they develop and support their scientific explanations for how populations of organisms can change over time and how they are connected to those long ago (SEP 7.3). A key goal of the unit is for students to be able to say not only what they think happened in these cases of natural selection but how the evidence supports that explanation (SEP 7.2, 7.3).

SEP8: Obtaining, Evaluating, and Communicating Information

SEP8 NGSS: The Elements of Obtaining, Evaluating, and Communicating Information in NGSS

SEP Elem	Description of Element of *Obtaining, Evaluating, and Communicating Information*
8.1	Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
8.2	Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
8.3	Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.
8.4	Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.
8.5	Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

SEP8 G6: Obtaining, Evaluating, and Communicating Information in Grade 6

Unit	Support for growth in Obtaining, Evaluating, and Communicating Information
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	
6.3 Weather, Climate & Water Cycling	**Key Use:** At key moments in the unit, students critically read scientific texts to obtain information to describe patterns in and/or evidence about the natural world (SEP 8.1), and they integrate qualitative and quantitative scientific information in written text with that contained in media and visual displays to clarify claims and findings (SEP 8.2).
6.4 Plate Tectonics & Rock Cycling	**Not a Focus**
6.5 National Hazards	**Intentionally Developed:** Throughout the unit students gather, read, synthesize and evaluate information from multiple sources, including text, data, maps, graphs, and images (SEP 8.1, 8.2, 8.3). The scaffolding around this practice fades so that by the final project, students independently gather, evaluate, synthesize, and communicate information with a guiding framework, but with flexibility to allow them to determine the sources of some of the information and how they will communicate it (SEP 8.5).

Unit	Support for growth in Obtaining, Evaluating, and Communicating Information
6.6 Cells & Development	**Key Use:** Students critically read texts and images to obtain scientific information at multiple points in the unit, including (a) analyzing injury to the foot and the recovery process, (b) describing patterns in the structures of the human leg, and (c) making sense of patterns in microscopic images of different parts of living organisms (SEP 8.1). Students gather, read, and synthesize information from images, scientific text, and diagrams to figure out the structure and function of different types of cells and their corresponding systems within the body (SEP 8.1, 8.3). Finally students communicate how the interactions between different parts of the body lead to healing and growth, and how various community healing methods support the role of cells in the healing process.

SEP8 G7: Obtaining, Evaluating, and Communicating Information in Grade 7

Unit	Support for growth Obtaining, Evaluating, and Communicating Information
7.1 Chemical Reactions & Matter	**Not a Focus**
7.2 Chemical Reactions & Energy	**Key Use:** Students design a homemade heater with the goal that anyone would be able to gather the materials and have them on hand to use in case of an emergency. Students need to communicate this technical information by creating easy to follow instructions for the homemade flameless heater they have designed (SEP 8.5). Throughout the design process groups present their designs orally for peer feedback. Students also test other students' heaters using only the written instructions they provided. Students use feedback at each step to revise their instructions and may enhance their instructions by adding diagrams or a "how-to video" (SEP 8.1, 8.5).
7.3 Metabolic Reactions	**Not a Focus**
7.4 Matter Cycling & Photosynthesis	**Key Use:** - Students critically read scientific texts and integrate information from written and visual displays such as infographics across many lessons, drawing on these sources in investigations of plant cells, food labels, plants doing cellular respiration and synthetic materials manufactured from algae, and the differences between natural and synthetic foods (SEP 8.1, 8.2, 8.3). Students also communicate scientific information about what they figured out in later lessons (SEP 8.5).
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students critically analyze texts and interviews to obtain information about how people receive ecosystem services from farming practices that promote stability in natural systems (SEP 8.1), and integrate qualitative information from texts and media to clarify claims about farming practices that reduce risk to disruptions in populations (SEP 8.2). At the end of the unit,, students communicate information in writing, drawing, and oral presentation about how small changes in people's behaviors (e.g., buying different products) can have large impacts on the preservation of natural systems such as the tropical rainforests where orangutans live (SEP 8.5).

Unit	Support for growth Obtaining, Evaluating, and Communicating Information
7.6 Earth's Resources & Human Impact	**Key Use:** Throughout the unit, students obtain, evaluate, synthesize, and apply information from informational texts, videos, tweets, graphs, maps, simulations, and data visualization tools (SEP 8.1, 8.2, 8.5). For example, they obtain additional information about components of the water system and are cued to evaluate the claims made by scientists and other reliable, valid sources and the data they use to support their claims (SEP 8.2). At the end of the unit, they evaluate and communicate carbon solutions to their chosen stakeholder audience (SEP 8.5).

SEP8 G8: Obtaining Evaluating and Communicating Information in Grade 8

Unit	Support for Obtaining Evaluating and Communicating Information
8.1 Contact Forces	**Not a Focus**
8.2 Sound Waves	
8.3 Forces at a Distance	
8.4 Earth in Space	**Key Use:** Throughout the unit students gather, read, and synthesize information from multiple sources including text, data, maps, graphs, and images (SEP 8.1, 8.2), building on their experience with this practice from prior units. While students continue to use several close reading and listening protocols, some of the scaffolding from previous units is now removed so they can execute the practice on their own.
8.5 Genetics	**Intentionally Developed:** Students work with a new element, synthesizing and evaluating information from sources to evaluate competing hypotheses and conclusions (SEP 8.4). Throughout the unit students obtain and evaluate information from a variety of sources, including articles, audio interviews, videos, charts, graphs, and images as part of making progress on their questions about inheritance of traits (SEP 8.1, 8.2, 8.3). They have formal and informal opportunities to communicate information orally and in writing (SEP 8.5). Students gradually become more independent in their use of the practice. To support their use of this practice, in an early unit students co-construct a version of the checklist tool they used in prior units and apply it in many later lessons with opportunities to obtain, evaluate, and communicate increasingly complex information. Students are formally assessed on this practice and complete a self-assessment to reflect on their use of obtaining and evaluating information at the end of the unit.
8.6 Natural Selection & Common Ancestry	**Key Use:** (SEP 8.1, 8.3)

Appendix D: CCC progressions - A Detailed Look

In this Appendix, we consider each CCC and describe how students build the elements of the CCC across the program. We use the CCC elements as defined in NGSS Appendix G, and for ease of reference, we have numbered them. The following tables present the elements of each CCC followed by a table showing the progression of the CCC in grade 6, 7, and 8.

CCC1: Patterns

CCC1 NGSS: The Elements of Patterns in NGSS

CCC Elem	Description of Element
1.1	Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
1.2	Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
1.3	Patterns can be used to identify cause and effect relationships.
1.4	Graphs, charts, and images can be used to identify patterns in data.

CCC1 G6: Patterns in Grade 6

Unit	Support for Growth in Patterns
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Intentionally Developed:** Students engage in all elements of this crosscutting concept across the unit. Students use patterns as a helpful lens during data analysis as students interpret temperature data from various investigations (CCC 1.2, 1.4). Students use macroscopic patterns to figure out the nature of interactions at the microscopic scale (CCC 1.1) and to identify cause and effect relationships (CCC 1.3).
6.3 Weather, Climate & Water Cycling	**Key Use:** (CCC 1.1, 1.2, 1.3, 1.4)
6.4 Plate Tectonics & Rock Cycling	**Key Use:** (CCC 1.3, 1.4)

Unit	Support for Growth in Patterns
6.5 National Hazards	**Key Use:** (CCC 1.3, 1.4)
6.6 Cells & Development	**Key Use:** (CCC 1.3, 1.4)

CCC1 G7: Patterns in Grade 7

Unit	Support for Growth in Patterns
7.1 Chemical Reactions & Matter	**Key Use:** Students look for patterns of macroscopic occurrences in the bath bomb's interaction with water to figure the particle level interactions that explain their observations(CCC 1.1). In the first half of the unit, students use patterns to help them determine that different substances are made of different, unique particles. In the second half, students develop the idea that these particles must be made of different parts (atoms) and that the way these parts are put together is unique to different substances. Students use patterns to help them refine and revise their explanation of the reaction between the substances of the bath bomb when placed in water (CCC 1.2, 1.3, 1.4).
7.2 Chemical Reactions & Energy	**Key Use:** (CCC 1.2, 1.3, 1.4)
7.3 Metabolic Reactions	**Key Use:** (CCC 1.2, 1.3, 1.4)
7.4 Matter Cycling & Photosynthesis	**Key Use:** (CCC 1.4)
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** (CCC 1.2, 1.3, 1.4)
7.6 Earth's Resources & Human Impact	**Key Use:** (CCC 1.2, 1.3, 1.4)

CCC1 G8: Patterns in Grade 8

Unit	Support for Growth in Patterns
8.1 Contact Forces	**Key Use:** (CCC 1.1, 1.2, 1.3, 1.4)

Unit	Support for Growth in Patterns
8.2 Sound Waves	**Key Use:** Students use patterns in early lessons to identify cause and effect relationships about sound sources and then mid-unit they notice patterns across investigations to identify that matter is needed for sounds to travel (CCC 1.3). In the first lesson set, students compare and contrast graphical representations of objects moving to identify patterns about how sound makers vibrate differently for low/high pitched or loud/soft sounds (CCC 1.4). Students also measure visual patterns in rate change of compression bands to see how changes in frequency and amplitude at the sound source affect the rate of movement of matter in the system, and they use charts and graphs to identify patterns in rates of change as they discover that energy is transferred differently for increases in frequency versus amplitude of vibrations (CCC 1.2).
8.3 Forces at a Distance	**Key Use:** (CCC 1.2, 1.3, 1.4)
8.4 Earth in Space	**Intentionally Developed:** As students make sense of phenomena in this unit, they work with very different kinds of patterns than they have seen before involving variations across the planet, solar system, galaxy, and universe, and across many years. From the start of the unit, students notice and analyze patterns in the sky, and throughout the unit they make note of additional patterns they and others observe in the sky and feel connected to (CCC 1.4). Students notice repeating patterns not just over days but thousands of years (CCC 1.2). They figure out how to expand these patterns to systems at great scale such as the organization of the solar system and galaxies and use patterns in the mechanisms of gravitational forces to explain them (CCC 1.3).
8.5 Genetics	**Key Use:** (CCC 1.2, 1.4)
8.6 Natural Selection & Common Ancestry	**Key Use:** Students use patterns in data to identify cause and effect relationships between the body structures of ancient and modern penguins, then use the patterns they've identified to determine that some of the traits in a population of descendents must have been changing over millions of years (CCC 1.2, 1.3). Students identify patterns related to the environment, heritability, and survival and reproduction in graphs of case study data and in the data produced by simulations. Students infer relative time spent in different environments based on patterns in the numbers of similar or different body structures between modern and ancient penguin species, and use sketches to identify particular similarities (patterns) between the physical structures of different species that are not evident in the fully-formed anatomy (CCC 1.4).

CCC2: Cause and Effect

CCC2 NGSS: The Elements of Cause and Effect in NGSS

CCC Elem	Description of Element
2.1	Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
2.2	Cause and effect relationships may be used to predict phenomena in natural or designed systems.
2.3	Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

CCC2 G6: Cause and Effect in Grade 6

Unit	Support for Growth in Cause and Effect
6.1 Light and Matter	**Key Use:** (CCC 2.2)
6.2 Thermal Energy	**Key Use:** (CCC 2.2, 2.3)
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** Students figure out cause-and-effect relationships throughout this unit, and they apply cause and effect to predict and explain phenomena with increasing independence and to increasingly more complex phenomena as the unit goes on (CCC 2.2). Students connect together relationships that have more than one cause and also connect together longer causal chain processes that occur in more steps then they encountered in prior units (CCC 2.3). For the first time in the program, students classify relationships as correlational (the relationship between temperature, humidity, and storm formation), noticing that when one variable increases, it increases the likelihood of another outcome (CCC 2.1).
6.4 Plate Tectonics & Rock Cycling	**Key Use:** This unit follows a thread of causal and correlational relationships in connection with mountain change (CCC 2.1). Students begin the unit by brainstorming potential causes of mountain movement - such as earthquakes, volcanoes, erosion, etc. Then through the unit they investigate how each of these processes happens and the effect they have on Earth (CCC 2.2).
6.5 National Hazards	**Key Use:** Students build a Tsunami Chain of Event diagram that links together cause-and-effect relationships (CCC 2.1) from what they figure out about tsunamis and use these relationships to predict tsunami phenomena (CCC 2.2).
6.6 Cells & Development	**Key Use:** (CCC 2.2)

CCC2 G7: Cause and Effect in Grade 7

Unit	Support for Growth in Cause and Effect
7.1 Chemical Reactions & Matter	**Not a Focus**
7.2 Chemical Reactions & Energy	**Key Use:** (CCC 2.2)
7.3 Metabolic Reactions	**Key Use:** (CCC 2.1, 2.2)
7.4 Matter Cycling & Photosynthesis	**Not a Focus**
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Cause and effect is a lens students apply throughout the unit, focusing on establishing cause and effect relationships in order to predict phenomena (CCC 2.2). Students use cause and effect in the context of natural systems and in their designs for land-use systems.
7.6 Earth's Resources & Human Impact	**Key Use:** In the first lesson set, students begin developing a cause-and-effect diagram that explains changing precipitation patterns in communities (CCC 2.2). They continue this work in the second lesson set as they question whether rising concentrations of gases in the atmosphere are correlationally or causally related to temperature change (CCC 2.1). From that point forward, they use the lens of cause-and-effect as they make sense of the mechanisms that regulate temperatures in the atmosphere. Students gather evidence and their final consensus carbon system model and cause-and-effect diagram for the unit combine their evidence to establish a causal relationship between fossil fuel use and changing water resources and the floods and droughts observed in the anchor lesson.

CCC1 G8: Cause and Effect in Grade 8

Unit	Support for Growth in Cause and Effect
8.1 Contact Forces	**Key Use:** (CCC 2.1, 2.2)
8.2 Sound Waves	**Key Use:** (CCC 2.2)
8.3 Forces at a Distance	**Intentionally Developed:** This unit supports students' development of cause-and-effect thinking through the application of cause-effect sentence frames throughout the unit. Early in the unit, students look for evidence of a relationship between the presence of air and the transfer of energy between two magnets and find that no relationship exists (CCC 2.1). At many points in the unit students use cause and effect relationships to predict phenomena, for example: how we hear sound from a speaker, what will happen when a

Unit	Support for Growth in Cause and Effect
	coil of wire is connected to a battery, and the changing direction of forces and shape of a magnetic field (CCC 2.2, 2.3).
8.4 Earth in Space	**Key Use:** Students use the CCC of cause and effect to figure out how light interacts with objects in the solar system and atmosphere (CCC 2.2). Students figure out the causes of the color changes we notice in the Sun and Moon when we see them at different points in the sky as they investigate the effects on sunlight of traveling through space (with few or no particles) compared to entering Earth's atmosphere (with various types of particles). Students develop a model to explain how light interaction with similarly structured matter (ice crystals and water droplets) can account for various natural phenomena, including rainbows.
8.5 Genetics	**Key Use:** Students' more independent use of cause-and-effect thinking is supported by removing scaffolds and applying these ideas to explain increasingly complex phenomena. Early in the unit, they use the cause-and-effect framing tool from 8.3 to predict outcomes and summarize investigation findings, and this tool is revisited with less scaffolding in several later lessons. Students also consider whether the relationship among alleles, proteins, and phenotype is causal or correlational (CCC 2.1). Throughout the unit, students develop and revise a model to explain the causes of extra-big muscles, and then to explain how both genetic and environmental factors contribute to other variations we see in living things (CCC 2.2). In their final models, as well as in their work calculating the probability of offspring phenotypes from various parental crosses, students apply the idea that some cause-effect relationships can only be described using probability (CCC 2.3).
8.6 Natural Selection & Common Ancestry	**Key Use:** Students use the crosscutting concept of cause and effect across the second lesson set as they develop their general model for natural selection, which then allows them to explain in the third lesson set how ancient and modern penguins are connected through changes over time (CCC 2.2). Students extend their thinking around cause and effect relationships that are probabilistic when developing and using the ideas that competitive (dis)advantage for particular trait variations are probabilistic in nature and that there is variability in the outcomes of natural selection (CCC 2.3).

CCC3: Scale Proportion and Quantity

CCC3 NGSS: The Elements of Scale Proportion and Quantity in NGSS

CCC Elem	Description of Element
3.1	Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
3.2	The observed function of natural and designed systems may change with scale.
3.3	Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different

CCC Elem	Description of Element
	types of quantities provide information about the magnitude of properties and processes.
3.4	Scientific relationships can be represented through the use of algebraic expressions and equations.
3.5	Phenomena that can be observed at one scale may not be observable at another scale.

CCC3 G6: Scale, Proportion, and Quantity in Grade 6

Unit	Support for Growth in Scale, Proportion, and Quantity
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Key Use:** (CCC 3.5)
6.3 Weather, Climate & Water Cycling	**Not a Focus**
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed:** Through the unit, students routinely work with scales that are too small or large to be observed in our given space and over our lifetimes (CCC 3.1). Students consider how plate movement happens very slowly, but over the course of millions of years, large plates can move great distances and at scales that can be seen globally (CCC 3.5). Students also use proportional relationships to guide their mathematical and computational thinking about plate movement processes (CCC 3.3), which is the first time in the program that they use that element of this crosscutting concept.
6.5 National Hazards	**Not a Focus**
6.6 Cells & Development	**Key Use:** Students use different spatial scales to observe and make sense of phenomena, from macroscopic (parts of the body, systems within the body) to the microscopic (cell level) (CCC 3.5). They also consider different temporal scales to figure out what the body is made of and how the different structures in the body are interconnected.

CCC3 G7: Scale, Proportion, and Quantity in Grade 7

Unit	Support for Growth in Scale, Proportion, and Quantity
7.1 Chemical Reactions & Matter	**Intentionally Developed:** In this unit, students develop a new aspect of this concept, working with the idea that some scientific relationships can be represented through mathematical expressions (CCC 3.4). Students calculate the density of a variety of substances from measurements of mass and volume (CCC 3.3). In addition to these

Unit	Support for Growth in Scale, Proportion, and Quantity
	elements, students work with another aspect of scale when they develop models to link the observerable macro level scale of what can be observed with the bath bomb to the particle level interactions at a scale too small to see.
7.2 Chemical Reactions & Energy	**Key Use:** (CCC 3.3)
7.3 Metabolic Reactions	**Not a Focus**
7.4 Matter Cycling & Photosynthesis	
7.5 Ecosystem Dynamics & Biodiversity	
7.6 Earth's Resources & Human Impact	**Key Use:** Students use scale, proportion, and quantity to make sense of the magnitude of change in greenhouse gases and the proportional relationship they have with temperature (CCC 3.3). Students examine the concentration of gases in the atmosphere, calculate the percent change over a 100-year time frame, and see that some gases make up a small proportion of the atmosphere, but those same gases are changing by a notable amount. Students develop a model idea that the concentration of GHGs in the atmosphere are proportionally related to temperatures. They use this relationship to problematize the magnitude of reduction in carbon dioxide emissions that must happen to see a temperature decline. Students calculate a carbon savings rate per person and scale this number to larger populations (CCC 3.2). In addition, students use scale models to study changes in the large scale water system (CCC 3.1).

CCC3 G8: Scale, Proportion, and Quantity in Grade 8

Unit	Support for Growth in Scale, Proportion, and Quantity
8.1 Contact Forces	**Not a Focus**
8.2 Sound Waves	**Intentionally Developed:** Students extend their understanding of phenomena happening at scales we cannot see by using a variety of tools to model and collect data about the vibrations that occur when objects make sounds, and how those sounds transfer energy across media (CCC 3.5). Students use scale in a new way to develop an experiment with a scaled up version of the phenomena so they can analyze non visible motions of objects making sound, and then throughout the unit they propose and evaluate other ways of scaling objects to provide evidence of what is happening when sounds are made. Students use proportional relationships to analyze information from numerical data and graphs of how the energy transferred by a vibration changes with the frequency vs. the amplitude

Unit	Support for Growth in Scale, Proportion, and Quantity
	from which they conclude that increases in amplitude have a greater effect on the energy transferred by a vibrating object than in frequency (CCC 3.3, 3.4).
8.3 Forces at a Distance	**Key Use:** (CCC 3.3)
8.4 Earth in Space	**Intentionally Developed:** To explain the patterns they see and develop explanatory models for the unit's phenomena, students need to work at dramatically different scales than they used in prior units. Students begin by modeling Manhattanhenge, which only involves a two-object system at one scale. By the end of the unit, students' models move from the scale of the Earth-Sun-Moon system to the scale of the universe, including galaxies, stars, and additional objects and subsystems in the solar system (CCC 3.1, 3.2, 3.5).
8.5 Genetics	**Key Use:** (CCC 3.5)
8.6 Natural Selection & Common Ancestry	**Not a Focus**

CCC4: Systems and Systems Models

CCC4 NGSS: The Elements of Systems and System Models in NGSS

CCC Elem	Description of Element
4.1	Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
4.2	Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
4.3	Models are limited in that they only represent certain aspects of the system under study.

CCC4 G6: Systems and System Models in Grade 6

Unit	Support for Growth in Systems and System Models
6.1 Light and Matter	**Intentionally Developed:** Students analyze the surprising behavior of the system of a one-way mirror, to figure out the components, interactions, and processes of the system. Students develop a model explaining how changes to light and changes to the material affect what we can see. Students zoom into different parts of the whole system to investigate subsystems such as the one-way mirror material and the eye and brain system

Unit	Support for Growth in Systems and System Models
	(CCC 4.1). By the conclusion of the unit, students understand what constitutes a system and have iteratively developed a systems model that describes how light interacts with objects and how reflected light is an input into the eye (CCC 4.2).
6.2 Thermal Energy	**Intentionally Developed:** While students began to work with models representing systems in the previous unit, in this unit they learn to construct particle-level models that represent energy flow in a system (CCC 4.2). Students construct a model of the cup system and identify important components and interactions that should be tested to figure out why the water warms up. The cup system model they develop through the unit targets tracing matter and energy inputs and outputs from the system to explain why water inside the system warms up.
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** In this unit, students define system boundaries in a system where such boundaries do not have visible physical structures, something they have not done before. Students also identify that the model they are using to investigate temperature and humidity is limited, and they revise it to include additional aspects (CCC 4.3). Throughout the unit, students represent the interactions, inputs, and outputs for both matter and energy within and across these systems for multiple processes: radiation, conduction evaporation, condensation, crystallization, convection, and uplift (CCC 4.2).
6.4 Plate Tectonics & Rock Cycling	**Not a Focus**
6.5 National Hazards	**Key Use:** Integrated with the Tsunami Chain of Events is a Hazard System Model that links components of subsystems with those science and engineering ideas about tsunamis (CCC 4.1). Students also focus on how communication systems are designed to send and receive messages using different types of signals or technologie focusing on information flows within the systems (CCC 4.2).
6.6 Cells & Development	**Key Use:** At the start of their investigations, the class develops a poster called *Our Body as a System*. Students incrementally revise and extend the systems model poster in the next several lessons as they figure out more about the different systems and subsystems within our body and how they interact, ranging from our body as a whole down to the system of the cell (CCC 4.1, 4.2).

CCC4 G7: Systems and System Models in Grade 7

Unit	Support for Growth in Systems and System Models
7.1 Chemical Reactions & Matter	**Not a Focus**
7.2 Chemical Reactions & Energy	**Key Use:** In the beginning of this unit, students build models that link components of subsystems with the science and engineering ideas they have developed about chemical reactions and energy transfer to represent what is happening in the Meal, Ready to Eat. In

Unit	Support for Growth in Systems and System Models
	the second lesson set, students also use system models representing inputs, processes, and outputs of energy and matter to design their own homemade flameless heaters (CCC 4.1, 4.2).
7.3 Metabolic Reactions	**Intentionally Developed:** Students develop the concept of multiple layers of subsystems working together in living things throughout this unit, with scaffolding along the way (CCC 4.1). At the beginning of the unit, students begin to make connections between the structure of an organ and its ability to perform a job inside of the digestive system. For example, students model what's happening in the mouth, but their model is limited to that subsystem (CCC 4.3). Later in the unit, they develop a model to represent the inputs, processes, and outputs of the digestive system and the role of that system and its subsystems in breaking down matter inputs through chemical reactions, absorbing food, and excreting unused matter (CCC 4.2). Later in the unit students use the concept they have built of multiple interacting systems from cells > tissue > organ > organ-system > whole body system to examine the trends of M'Kenna's stagnant growth and weight loss.
7.4 Matter Cycling & Photosynthesis	**Intentionally Developed:** This is the first time students model the interactions of both living and nonliving systems together. Students begin the unit by modeling at the macro scale the proposed inputs and outputs an individual plant system needs for food. As the unit progresses, students revise those inputs based on evidence and include the interactions inside the plant system and subsystems (cells and cell substructures) to rearrange the matter and energy into food. Students expand those micro subsystems of plants to include reactions in other cell substructures. Students then follow the flow of transfer of energy within the plant and then out of the plant into animals, decomposers, synthetic materials, and the nonliving components within an ecosystem (CCC 4.1, 4.2, 4.3).
7.5 Ecosystem Dynamics & Biodiversity	**Key Use:** Students develop system models to allow them to understand the different components and interactions occurring within the system (CCC 4.1, 4.2). They discuss limitations of their system models (such as simulations) for representing the complexity of the real-world systems (CCC 4.3).
7.6 Earth's Resources & Human Impact	**Key Use:** (CCC 4.1, 4.2)

CCC4 G8: Systems and System Models in Grade 8

Unit	Support for Growth in Systems and System Models
8.1 Contact Forces	**Key Use:** (CCC 4.1, 4.2)
8.2 Sound Waves	**Not a Focus**

Unit	Support for Growth in Systems and System Models
8.3 Forces at a Distance	**Key Use:** Students spend the unit breaking down and modeling the speaker system, describing and explaining the system in terms of its components and interactions (CCC 4.2).
8.4 Earth in Space	**Intentionally Developed:** All of students' work with the practice of modeling and the crosscutting concepts of scale and patterns leverages related crosscutting ideas about systems and system models. Students begin to make sense of the parts and interactions in the system to explain the causes of patterns in the sky. Models throughout the unit link components about the motion, positions, and appearance of objects within their subsystems and placement within larger systems (CCC 4.1). Students also model the way that light refracts as it travels into and out of different mediums and how small changes, such as slight changes in the mass or distance between two objects, can change the strength of the gravity force interacting between the two objects (CCC 4.2).
8.5 Genetics	**Not a Focus**
8.6 Natural Selection & Common Ancestry	

CCC5: Energy and Matter

CCC5 NGSS: The Elements of Energy and Matter in NGSS

CCC Elem	Description of Element
5.1	Matter is conserved because atoms are conserved in physical and chemical processes.
5.2	Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
5.3	Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
5.4	The transfer of energy can be tracked as energy flows through a designed or natural system.

CCC5 G6: Energy and Matter in Grade 6

Unit	Support for Growth in Energy and Matter
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	**Intentionally Developed:** In the first lesson set, students focus on tracing matter through physical changes, drawing on the idea that matter is conserved (CCC 5.1). The remainder

Unit	Support for Growth in Energy and Matter
	of the unit focuses on tracing energy and accounting for energy transferring within and between systems (CCC 5.3, 5.4).
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** As they develop a model for temperature differences in matter causing convection currents that move air, students focus on a new element of this concept, figuring out that the transfer of energy can drive the motion of matter in a system (CCC 5.2). They also develop the idea that state changes are also caused by the transfer of energy, which in turn also drives the cycling of matter in and out of the atmosphere (CCC 5.3, 5.4).
6.4 Plate Tectonics & Rock Cycling	**Not a Focus**
6.5 National Hazards	
6.6 Cells & Development	

CCC5 G7: Energy and Matter in Grade 7

Unit	Support for Growth in Energy and Matter
7.1 Chemical Reactions & Matter	**Key Use:** Students develop and use the idea of conservation of matter in this unit to explain what happens to matter during a chemical reaction (CCC 5.1). Note that the energy component of this crosscutting concept in relation to a chemical reaction is not explored or explained in this unit since students will focus on that in the unit that directly follows this one. In this unit, students have many opportunities to engage with and use this crosscutting concept to develop their model of what happens to the atoms of molecules that make up reactants in a chemical reaction and compare this to the atoms in the molecules of the products. Through multiple investigations students collect evidence of the mass of the system before and after reacting. By the end of the unit, students figure out that matter is conserved and cannot appear or disappear. This idea supports their explanation about what products are made from the bath bomb reaction.
7.2 Chemical Reactions & Energy	**Intentionally Developed:** Students have tracked energy through a system in prior units, but here they work in another context: energy transfer resulting from a chemical reaction. Throughout the unit, students consider the transfer of energy between parts of the system they are designing and the impact of the matter—how the substances that are part of the chemical reaction system are changed and how amounts of matter in the chemical reaction system and the food system impact design decisions (CCC 5.2, 5.4).
7.3 Metabolic Reactions	**Key Use:** This unit introduces the concept of food (matter) as fuel (energy) and lays the groundwork for future units in which students figure out that both food and other sources of fuels are sources of matter and sources of energy, drawing connections

Unit	Support for Growth in Energy and Matter
	between chemical reactions that transfer and convert energy in living and nonliving systems (CCC 5.1, 5.2).
7.4 Matter Cycling & Photosynthesis	**Intentionally Developed:** Students extend their models of matter and energy flow from prior units to the interactions between living and nonliving components of ecosystems (CCC 5.1, 5.2). Throughout this unit, students gather evidence for the transfer of energy and cycling of matter for plants, animals (which began in the prior unit), decomposers, and the abiotic parts of ecosystems. They incrementally model the transfer of energy and cycling of matter from the abiotic parts of an ecosystem into, within, and out of plants back into the ecosystem, into other living things, or into designed systems to create synthetic materials (CCC 5.3, 5.4).
7.5 Ecosystem Dynamics & Biodiversity	**Not a Focus**
7.6 Earth's Resources & Human Impact	**Key Use:** (CCC 5.1, 5.2, 5.4)

CCC5 G8: Energy and Matter in Grade 8

Unit	Support for Growth in Energy and Matter
8.1 Contact Forces	**Key Use:** (CCC 5.2, 5.4)
8.2 Sound Waves	**Key Use:** Students use what they figured out about energy transfer in prior units to figure out how the transfer of energy from a force causes a sound source to vibrate which transfers energy to neighboring particles across a medium, and those particles collide with another object, transferring energy to make it move (CCC 5.2). Students track the transfer of energy across the system from the sound source to the sound detector (CCC 5.4).
8.3 Forces at a Distance	**Key Use:** Students figure out and apply the idea that energy can be transferred in various ways and between objects in order to explain how the speaker system works (CCC 5.2, 5.3, 5.4).
8.4 Earth in Space	**Not a Focus**
8.5 Genetics	
8.6 Natural Selection & Common Ancestry	

CCC6: Structure and Function

CCC6 NGSS: The Elements of Structure and Function in NGSS

CCC Elem	Description of Element
6.1	Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.
6.2	Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used

CCC6 G6: Structure and Function in Grade 6

Unit	Support for Growth in Structure and Function
6.1 Light and Matter	**Intentionally Developed:** Students consider how the shape and composition of key components in the system help determine the function of those components. Students investigate the microscale composition (structure) of the one-way mirror, and figure out that the one-way mirror is designed with half-silvering, which affects the amount of light transmitted and reflected (CCC 6.2). Students explore the shapes and components of the human eye to understand how light inputs are processed into what we see. Students learn that the lens of the eye, because of its structure (shape and composition), refracts light to a point on the retina, where light signals are changed into electrical signals that are sent to the brain along the optic nerve (CCC 6.1).
6.2 Thermal Energy	**Intentionally Developed:** While students began their work with structure and function in the prior unit, in this unit they build on ideas about how properties of materials affect function by considering interactions at the particle level to inform their designs (CCC 6.1). In the third lesson set, students think about design features, or structures, and how they function to minimize energy transfer (CCC 6.2).
6.3 Weather, Climate & Water Cycling	**Not a Focus**
6.4 Plate Tectonics & Rock Cycling	
6.5 National Hazards	**Key Use:** Students investigate existing tsunami mitigation solutions and analyze how their shapes are designed to disperse the energy from a tsunami wave, and consider the community impacts (CCC 6.2). Students evaluate graphic and media-related communication options to consider how they are structured (with text, symbols, language, etc.) and how well they will function to meet stakeholder needs (CCC 6.1).

Unit	Support for Growth in Structure and Function
6.6 Cells & Development	**Key Use:** As students figure out how parts of the body heal, they investigate the way different parts are structured, how these parts function and how the way these parts are structured is related to the function of the part. Students look at structures both macroscopically in the body as well as microscopically down to the cell. Students figure out that the different parts of the body are made of cells that are unique in shape and composition to that part of the body and that the structure of the cell is related to the structure and function of the part of the body the cell comes from (CCC 6.1).

CCC6 G7: Structure and Function in Grade 7

Unit	Support for Growth in Structure and Function
7.1 Chemical Reactions & Matter	**Not a Focus**
7.2 Chemical Reactions & Energy	
7.3 Metabolic Reactions	**Key Use:** Students explicitly use a structure-function lens to develop their understanding of how structures within biological systems are organized and break down food for energy or growth through a series of chemical reactions (CCC 6.1). For example, students analyze and interpret data from six different data sets to use as evidence that the digestive system is a system of interacting subsystems composed of organs that each perform different functions. Students also analyze and interpret data to identify the relationship that taller villi (structure) have more cells that work together to impact the rate of absorption (function) of food molecules into the bloodstream.
7.4 Matter Cycling & Photosynthesis	**Not a Focus**
7.5 Ecosystem Dynamics & Biodiversity	
7.6 Earth's Resources & Human Impact	

CCC6 G8: Structure and Function in Grade 8

Unit	Support for Growth in Structure and Function
8.1 Contact Forces	**Intentionally Developed:** Students develop the idea that complex microscopic structures and systems can be visualized, modeled, and used to analyze how their function depends on the relationships among its parts in the third lesson set, building and testing a scaled up version of the space and air cavities found in many of the most effective cushioning materials (CCC 6.1). Although students have encountered parts of this idea in prior units, in this unit students develop larger scale models of microscopic structures and test them to figure out why they function the way they do (CCC 6.2).
8.2 Sound Waves	**Not a Focus**
8.3 Forces at a Distance	
8.4 Earth in Space	
8.5 Genetics	**Key Use:** Students explicitly use a structure-function lens to consider several of the ideas they're developing in this unit. Specific wording in videos and readings as well as guiding questions on handouts and slides and in discussions scaffold students as they explore structure-function relationships in complex biological systems (CCC 6.1). They investigate how proteins have specific structures to do their jobs, and they learn that if there is a change to the structure of a gene it can affect the protein produced. Students also investigate the specialized structures of plants that affect the probability of successful reproduction.
8.6 Natural Selection & Common Ancestry	**Key Use:** Students bring a vast amount of experience with structure/function thinking into this unit from prior work which they now use to support their investigations and make sense of data in almost every lesson. As they consider how organisms could be connected over time, students analyze the body structures of those organisms and consider how they function in similar or different ways and in similar or different environments (CCC 6.1). The models they develop for natural selection and common ancestry are informed by structure/function thinking.

CCC7: Stability and Change

CCC7 NGSS: The Elements of Stability and Change in NGSS

CCC Elem	Description of Element
7.1	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CCC Elem	Description of Element
7.2	Small changes in one part of a system might cause large changes in another part.
7.3	Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
7.4	Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.

CCC7 G6: Stability and Change in Grade 6

Unit	Support for Growth in Stability and Change
6.1 Light and Matter	**Not a Focus**
6.2 Thermal Energy	
6.3 Weather, Climate & Water Cycling	**Intentionally Developed:** This is the first time students figure out how to explain stability and change in systems by tracking particle interactions over time and at different scales (CCC 7.1). Students extend their particle level model developed in prior units to explain how a parcel of fluid such as air will rise, fall, or remain in a stable position based on particle interactions. They also extend this particle level model to explain why the state of water is relatively stable above or below a certain temperature, but a state change occurs when that temperature threshold is crossed.
6.4 Plate Tectonics & Rock Cycling	**Intentionally Developed:** Throughout this unit, students consider the small changes that occur to Earth's surface yearly (such as plate movement rate or rates of erosion versus uplift) to determine that while we cannot see these changes from day to day, we can see these changes over larger temporal and spatial scales (CCC 7.1). Students also focus on a new aspect of stability and change when they investigate earthquakes to determine that they are sudden events that are the result of gradual changes that add up over time (CCC 7.3).
6.5 National Hazards	**Intentionally Developed:** Students build on their use of this concept from the previous unit as they make sense of gradual changes to consider the rate of onset of hazards and how quickly a "sudden event" can disrupt the stability of a system (CCC 7.3). This aspect of the crosscutting concept is used to consider how people will need to respond in such an event.
6.6 Cells & Development	**Not a Focus**

CCC7 G7: Stability and Change in Grade 7

Unit	Support for Growth in Stability and Change
7.1 Chemical Reactions & Matter	Not a Focus
7.2 Chemical Reactions & Energy	
7.3 Metabolic Reactions	
7.4 Matter Cycling & Photosynthesis	
7.5 Ecosystem Dynamics & Biodiversity	**Intentionally Developed:** Students engage with a new aspect of this concept focusing on how the stability of a system in dynamic equilibrium, such as the orangutan population, depends on mechanisms that are in balance (CCC 7.4). Stability and change is a consistent lens students apply throughout the unit as they make sense of small changes in the system that have large impacts, as well as sudden and gradual changes over time (CCC 7.1, 7.2, 7.3). They look to stabilize orangutan populations and farmers' income in their final designs.
7.6 Earth's Resources & Human Impact	**Intentionally Developed:** Students use the lens of stability and change in their models when they explain how a small change in temperature could lead to large changes, like floods and droughts (CCC 7.2). Students also use the concept of stability and change to make sense of the current level of greenhouse gas concentrations in comparison to short-term and long-term data (CCC 7.1). In the final lesson set, students ask questions about different CO_2-reducing solutions and how gradual changes over time might lead to a reduction in atmospheric carbon dioxide and global temperatures. One aspect of the final project is to communicate a message about how small changes in behavior or the use of technology, when done across a larger group of people over a sustained time, can have a greater impact on atmospheric CO_2 (CCC 7.4).

CCC7 G8: Stability and Change in Grade 8

Unit	Support for Growth in Stability and Change
8.1 Contact Forces	**Intentionally Developed:** This unit expands the scale that students consider for explanations of changes over time at different scales (CCC 7.1). Students consider forces on and within substructures that make up cushioning materials. Students also examine particle level force interactions due to air resistance and surface friction to account for why the objects that were moving in a system (a cart and box) slow down and eventually stop (CCC 7.2, 7.3).

Unit	Support for Growth in Stability and Change
8.2 Sound Waves	Not a Focus
8.3 Forces at a Distance	
8.4 Earth in Space	
8.5 Genetics	
8.6 Natural Selection & Common Ancestry	**Key Use:** Students frequently use stability and change thinking as they evaluate trait variations in populations before and after an environmental change. In the first lesson set, students explain why there are similarities and differences in the body structures of modern and ancient penguins which highlights what has remained stable and what has changed in the different species' body structures over time (CCC 7.1, 7.2). In the second lesson set, students develop the idea that the trait variations found in a population may shift relatively rapidly due to sudden environment changes, and that trait variations found in a large population may remain relatively stable when the environment doesn't change. Students figure out that seemingly small changes in organisms can accumulate over generations and add up to relatively large amounts of change over long periods of time (CCC 7.3).

Appendix E: Development Process for the Scope and Sequence

Step in Process	Heuristic	Description
1. Create PE Bundles	*1a. Bundle related ideas*	Bundle PEs coherently so that students are bringing together related ideas to make sense of phenomena or solve problems.
	1b. Bundle PEs needed for mechanisms	Explain large scale macroscopic phenomena (weather, plate interactions, planetary motion) using mechanisms rather than facts and descriptions (e.g. figure out how gravity and motion explain why planets travel in elliptical orbits vs. just learning that planets travel in such orbits).
2. Establish Connections Across Units	*2a. Build explanations of phenomena using already established mechanisms*	Organize units so that mechanisms constructed in one unit can be used as explanatory mechanisms for subsequent units (e.g., build metabolic reactions on an earlier developed model of chemical reactions).
	2b. Refine ideas across time	Support students in using explanatory ideas (particularly DCIs) from an earlier unit again in new related contexts, revising and extending the ideas to address the new contexts. Articulate connections both within and between science strands, and both within and across grades.
	2c. Combine across disciplinary strands when needed for explanation of unit phenomena or solving problems	Do not integrate simply for the sake of integrating science strands. Combine ideas across strands when the additional disciplinary core ideas are needed to explain the mechanism at a grade-appropriate level.
3. Group Bundles Into Years	*3a. Sequence within and across grades to enable unit-to-unit connections*	Organize the units into a sequence within and across grades so that the sequence enables refining ideas across time as needed for the coherence articulated in steps 2a and 2b.
	3b. Use grade-level math	Ensure that PEs that require common core math are placed at or after the grade at which the math ideas will be developed.
	3c. Engineering across grades	Use and revisit different combinations of the four MS-ETS PEs in each grade.
	3d. Balance science strands	Ensure that each of the three science strands - earth & space, physical, and life sciences are relatively balanced in each grade.
	3e. Balance grades	Balance the number of PEs and the time to address them across the three grades. Avoid too many complex PEs in grade 6.