DESIGN SPECFCIATIONS

Introduction

Many considerations must be taken into account in designing instructional materials to create a product that lives up to the expectations of students, teachers, schools, and districts. There are the obvious and necessary elements that must be addressed, such as standards, scope and sequence, instructional model, and pacing. OpenSciEd instructional materials are thoughtfully constructed with all of these considerations and constraints in mind. Yet, these elements are not enough. Instructional materials must have a classroom vision, an image of how students will engage with the content, what type of discourse students will engage in, and a sense of what a teacher needs to make standards come alive.

OpenSciEd's beliefs about a science learning and vision of the classroom are embodied in our design specifications. These fourteen specifications describe what we want science learning to look like for every student, and therefore guide our materials development process and implementation support. The topics addressed range from equitable science instruction and the centrality of asking questions, to meeting practical needs and constraints of a classroom. These specifications are based on *A Framework for K-12 Science Education* and the resulting *Next Generation Science Standards*, including the emphasis on three-dimensional learning.

On the following pages are detailed descriptions of each design specification:

1–Instructional Model 3
2–Equitable Science Instruction for All Students 12
3–Assessment to Inform Teaching and Learning 25
4–Designing Educative Features 31
5–Asking Questions and Defining Problems 38
6–Planning and Carrying Out Investigations 45
7–Developing and Using Models, Constructing Explanations, and Designing Solutions 50
8–Analyzing and Interpreting Data and Using Mathematical and Computational Thinking 55
9–Arguing from Evidence and Obtaining, Evaluating, and 64

Communicating Information
10–Crosscutting Concepts 75
11–Classroom Routines 81
12–Integration of English Language Arts and Mathematics 85
13–Meeting Practical Needs and Constraints of Public Education 90
14–Guidance on Modifying Instructional Units 95
Credits 97

1–Instructional Model

Instructional materials provide a coherent path anchored in students' own experiences and questions to build disciplinary core ideas and crosscutting concepts through an iterative process of questioning, investigating, modeling, and constructing explanations. Students experience learning as *meaningful* (making sense of ideas rather than just reproducing them), *cumulative* (learning challenges require them to use and build on what they figured out in previous lessons), and *progressive* (the class improves explanations or solutions over time by iteratively assessing them, elaborating on them, and holding them up to critique and evidence).

1.1 Units are organized into a coherent storyline.

In a coherent storyline, the flow of lessons builds toward three-dimensional performance expectations while making sense to students from their own perspectives.

1.1.1. Units are organized as a sequence of lessons designed to build toward a bundle of NGSS performance expectations. The logic of the sequence should reflect a storyline that makes sense to students, where each lesson is motivated by questions students generate in order to explain phenomena, or in the case of design challenge units, to solve a problem. Questions come from the original anchoring phenomena or challenge, and from new puzzles that arise as students make progress on their models, explanations, or solutions.

1.1.2. The overall instructional flow of a unit involves a series of lessons that guide teachers and students to work together to establish the driving question or design challenge for the unit; put together a sequence of investigations to develop elements of science ideas or design solutions; and put these elements together to develop a model that can be used to explain the phenomena or solve the problem. The lessons support ongoing reflection and navigation discussions in which teachers and students evaluate their progress and determine next steps. The sequence culminates with putting pieces together, which compares competing possibilities and assembles elements of a model, an explanation, or design solution developed across the unit and evaluates its completeness, which may lead to additional cycles of further questions and investigation.

1.1.3. Each lesson has a clear goal, explicit for students, of improving some part of a model or explanation for phenomena, or contributing to the solution of a problem.

1.1.4. Each lesson is designed to enable students to make progress on their questions by using science and engineering practices and crosscutting concepts to help figure out a part of a science idea or make progress on the design challenge. Each idea they develop in greater depth adds to the developing explanation, model, or design solution. Each step may also generate new questions that add to students' work in the unit.

1.1.5. To support the flow of the storyline, each lesson contains guidance for teachers to co-construct the *framing* of the lesson with students so it builds toward the target performance expectations and clearly links to what students have identified in prior lessons as areas to extend or questions to address. The framing involves both the focus of the work (questions to address) and the way the class will make progress (develop new hypotheses, test ideas through investigation, argue with evidence, revise explanations, represent and compare ideas).

An example of a coherent storyline is the investigation of metabolic reactions in body systems in the OpenSciEd Prototype Unit 7.1. Rather than taking students through body systems, one by one, because the instructional materials provide a list of body systems to be studied, lessons elicit student questions based on a clinical case of a teenager who is inexplicably having digestive problems, losing weight, and lacking energy. Students' initial hypotheses and models are used to motivate questions, places, or processes in the body to be studied.

A non-example is a series of biology lessons (nutrient cycles, species interdependence, limiting factors) that all are related to a broader topic (ecosystems) but do not explicitly help students construct the knowledge needed to understand and explain a complex ecological phenomenon, do not reference and build upon one another, and do not follow a trajectory from more basic and familiar concepts to more complex and unfamiliar ones.

1.2 Anchoring phenomena and challenges drive the units.

Learning is motivated by attempting to make sense of initial phenomena or problems students identify related to the science learning targets, leading to iterative cycles of investigating phenomena, improving explanations, models, or designs with new evidence, and further questioning.

1.2.1. Students' experience with the anchoring phenomena (or the unit problem, in the case of challenge-based units) drives the work of the unit. An anchoring phenomenon is an occurrence in the world that can raise questions for students about how and why this event happens, or pose challenges for designing a solution to a problem. Investigating their questions or developing design solutions for the problem provide a context and motivation for students to figure out the target science ideas, and builds a shared mission that a classroom learning community needs to figure out phenomena or solve a design problem. The anchoring phenomenon grounds student learning in a common experience and then uses that experience to elicit and feed student curiosity, which then drives learning throughout the unit.

1.2.2. Students' experience of the anchoring phenomenon includes several essential elements (order may vary):

a. Students *encounter and explore* a phenomenon or problem in a way that enables them to experience the intriguing nature of the phenomenon or problem and to publicly, as a learning community, acknowledge aspects of the phenomenon that require explanation or solution.
b. Students *attempt to make sense* of the phenomenon or problem in a way that enables them to see what is important and difficult to explain, or aspects

that are problematic and require solution, and to generate questions that can guide future investigations or designs.

c. Students have the opportunity to *connect their prior knowledge and experiences* to the anchoring phenomenon or problem in order to broaden the scope of what the class is interested in figuring out and for students to have a personal connection and investment to the events being explored.

d. Students work together as a class to *develop questions* about the anchoring phenomenon or problem and generate ideas for how to answer those questions or generate solutions through investigations and designs they will conduct as part of the unit.

1.2.3. Instructionally productive anchoring phenomena have these characteristics:

a. Anchoring phenomena are not topics, themes, or engineering challenges used to organize a unit. For example, instead of simply learning about the topics of photosynthesis and mitosis, students should be building evidence-based explanatory ideas that help them figure out how a tree grows.

b. Anchoring phenomena require that students draw upon a range of science concepts and ideas and engage them in a number of investigations to build knowledge or solve a problem. The units support students in integrating these concepts and ideas into individual and group explanations or models that get increasingly sophisticated over time.

c. Anchoring phenomena or problems are set in contexts that are relevant to students' interests, cultures, or lived experiences, so that students' background knowledge and frames of reference are assets for their sense-making work.

d. Design challenge units also begin with anchoring phenomena. Problems that require solutions should arise from phenomena, and students should use explanations of phenomena to design solutions.

1.2.4. Anchoring phenomena are augmented by other phenomena during the unit. They should provide the initial focus for what needs to be explained or solved for the unit. As students make progress, partial models lead to new questions, which motivate bringing in additional investigative phenomena that can help make progress on these questions. A single phenomenon doesn't have to cover an entire unit, and different phenomena may take different amounts of time to figure out.

As in the earlier example, posing a question or problem about the investigation of metabolic reactions through the lens of an illness creates a context that is relevant and engaging for students. It transcends the separate facts or topics, challenging students to build a more complete understanding of the science concepts and ideas at work in the problem. There are multiple legitimate ways to represent what might be happening in the body and different students may choose to elaborate on unique aspects of the explanation or model.

A non-example of an anchoring phenomena or problem is a series of biology lessons that take students through each body system, its parts and their functions, and diseases of each system.

1.3 Learning as a classroom community is supported through a flow of activity that includes individual, pair, small group, and whole group discussion.

Students are explicitly positioned as collaborators, not competitors, who work as a community to figure something out about the natural or designed world. To enable access and participation for all students, lessons lead up to argumentation, explanation, and modeling in whole group contexts by providing opportunities for students to work out their thinking and talking in individual, pair, and small group contexts prior to whole group discussions.

1.3.1. Tasks are set up for students to engage in the science and engineering practices through a balance of individual or pair work, small group work, and whole class work.

1.3.2. Key steps in figuring out phenomena and solving problems require involvement of the learning community. Classroom routines support students in the work of scientific argumentation and negotiating consensus in order to identify questions, develop plans, and develop explanations and models. Learning sequences should culminate in lessons specifically focused on evaluating alternatives, scientific argumentation, and reaching consensus.

1.3.3. Units support students in participating in the learning community through a sequence that provides time first for individual and pair work, leading to small group work, and then engagement in whole group discussion. This allows students to develop their initial ideas by sharing and listening to others, and receiving and giving feedback, providing less stressful opportunities to build the confidence necessary to engage in whole class discussion.

1.3.4. Engaging in science and engineering practices focuses on sharing, critiquing, defending, and negotiating ideas. Units provide supports for students to articulate their ideas and make them public so that the full community can have access to them. Instructional materials contain opportunities for students to see and engage with each other’s ideas. Supports include general pedagogical approaches such as think-pair-share or jigsaw, and science-specific activity structures, such as gallery walk, driving question boards, or summary charts.

1.3.5. Instructional materials provide support for students to engage in scientific discourse and to learn the use of scientific representations to support this collaboration.

1.3.6. Units support both individual representation of the ideas by students in their notebooks, and public representations of the class consensus on what they have figured out. Individual and public artifacts keep track of the class questions, their plans, and their progress on models, explanations, and designs. Individual work provides the resources for group and whole class work, and provides space for students to develop, document, and apply their understanding. Both individual and collective work is central to documenting and guiding progress.

1.4 Students engage in incremental revision and synthesis of ideas.

Supporting three-dimensional learning is an incremental process. Developing explanatory ideas requires figuring out pieces of ideas and then assembling them into more complex explanations, models, or designs, developing intermediate models or designs that are partially successful, and providing opportunities for students to revise and improve those ideas.

1.4.1. Teacher materials provide guidance for teachers to work with students to incrementally develop, test, critique, and refine explanations and models over the course of a unit. Identification of needed revisions in models may arise from the introduction of new phenomena, classroom argumentation as part of building and evaluating models, new evidence, new investigations students ask to conduct, and new evidence from readings.

1.4.2. Each unit includes multiple opportunities for students to synthesize ideas they have developed across multiple lessons into a coherent model, explanation, or design.

1.4.3. Lessons ask students to share knowledge products that depict their current thinking: models, conceptual drawings, lists of hypotheses, partial explanations, or designs. Students' representations are referred to as "works in progress" and lessons support students in critiquing and revising these ideas over the course of the unit.

1.4.4. Lessons make coherent connections to preceding lessons to enable the synthesis and revision of ideas. Lessons include planned discussions in which teachers guide students to articulate the current state of the class' explanations, models, or designs, and identify pending questions to resolve, in order to connect the current lesson to the past work.

An example of incremental revision and synthesis of ideas is the class sound model in OpenSciEd Prototype Unit 8.1. The class develops an initial model for how sound is produced, travels, and can be detected, which consists primarily in the delineation of these three events, with underlying causes being black boxed. During the course of the unit, students work out causal models for each of these three elements (creation of sound, sound traveling, sound detection), and incrementally revise their models to incorporate these new findings. A first revision adds the idea of vibration of matter as the cause of sound. Later revisions add more detailed modeling of vibration as mathematical relationships including frequency and wavelength, and explain sound traveling through particle collision in a medium. Students' final models reflect a molecular-motion model in which energy is transferred through a medium.

A non-example is having students produce models or explanations for isolated phenomena that do not connect to questions or problems that have been raised, and are produced without revision or later use. Another non-example is having students produce public representations of their thinking for the sole purpose of labeling some of the ideas as correct or incorrect.

1.5 Units fit into the scope and sequence with explicit connections.

Units are designed to support a coherent learning experience. Each unit builds explicitly on the elements of disciplinary core ideas, practices, and crosscutting concepts that have been established in earlier units.

1.5.1. Teacher materials contain explicit connections for teachers to help students build on the disciplinary core ideas and crosscutting concepts established in prior units. Where connections are identified in the scope and sequence between two performance expectation bundles, the unit reflecting the later bundle includes early lessons in which teachers work with students to explicitly identify relevant elements of disciplinary core ideas and crosscutting concepts from prior work that can help partially address the anchoring phenomena or problem. Students also bring in ideas established in earlier grades. The modeling, explanation, and design work builds explicitly on the earlier ideas students have identified.

1.5.2. Instructional materials contain explicit connections for teachers to help students access and build on the science and engineering practices and crosscutting ideas established in prior grades and in prior units. While students are engaging in all three dimensions K-12, their progression not only builds through their explanatory power of the disciplinary core ideas, but also in their ability to flexibly use the science and engineering practices and crosscutting concepts to develop grade-appropriate explanations of phenomena, even if they have encountered similar events in prior units. Lessons guide teachers and students in identifying how they have engaged in the practices in prior units or grades, and build in grade-appropriate advances in the unit.

1.6 Engineering practices are used in units when it furthers the science.

Units use science and engineering together when appropriate. When engineering practices are included, those practices also help students deepen the relevant science.

1.6.1. Units include engineering practices when they can deepen science learning. Engineering practices are always paired with disciplinary core ideas from life, earth and space, or physical science. Engineering practices are not used just in combination with engineering disciplinary ideas, that is, solely to learn about the nature of engineering.

1.6.2. Engineering challenges provide opportunities for students to deepen their explanations and models of scientific phenomena. Engineering challenges do not simply draw from and ask students to apply science that students have already learned, or if students are able to use trial-and-error to find a solution to the problem, without drawing on science ideas for their solution.

2–Equitable Science Instruction for All Students

Recognizing the vast range of student diversity in today's classrooms and the deep injustices in society, instructional materials build on guidelines in *A Framework for K-12 Science Education* and the NGSS to support learners who come from non-dominant communities or are underrepresented in STEM. Instructional materials guide teachers in implementing equitable science instruction for all students, and are flexible enough to be adapted to fit teachers' and students' local circumstances. The practices described in the equity design specifications are central to science teaching and learning everywhere and for all students; they are not add-on strategies that only need to be deployed in the presence of students from historically underserved communities. Professional development that supports implementation of the instructional materials must focus on these equity practices.

Equity Design Stance: Instructional materials are rooted in a commitment to restorative justice through privileging multiple ways of knowing, being, and valuing as a fundamental human condition, and they promote the rightful presence for all students across the multifaceted scales of justice, including scales related to race, socioeconomic class, gender, educational sovereignty, Indigenous rights, immigration history, land and water rights, sexual orientation, gender expression, abilities, and other dimensions of social difference related to justice. From a critical historical perspective, working towards equity and justice involves implementing approaches that de-settle inequitable systems, routines, and assumptions that are likely to be in place in many educational institutions. In coordination, it is then possible to support expansive cultural learning pathways for youth working from an asset perspective. In particular, these pathways should be designed to center the lifeworlds on non-dominant communities in support of multiple ways of knowing, being, and valuing. As detailed in *A Framework for K-12 Science Education*, all science learning is a cultural accomplishment.

Diverse Design Teams: To design for equitable instruction, instructional designers need to acknowledge and account for the design bias that relates to the cultural diversity and history of their team. Teams should include designers from a range of experiences and backgrounds, or recruit consultants who can attend to issues that arise from homogeneity and socially dominant positioning, in order to better de-settle oppressive curricular representations and pedagogical practices. Design teams should include designers who reflect the experiences along race, ethnicity, culture, gender, class, and/or ability of the students who will learn with the OpenSciEd instructional materials. While it may not be possible for design teams to include members that identify with *all* of these identities, it is important for designers with (some of) these experiences to be present throughout the work at all times, rather than brought on only as special consultants to review the work produced by designers who identify with dominant groups. Many of the design recommendations depend upon the instructional design knowledge of people who have specific equity-focused expertise—such individuals will need to be meaningfully integrated into design teams in order to attend to equity and justice in the design of instructional materials.

2.1 Diversity is made visible.

Individuals, teams, and communities from all nations and cultures have contributed to science and to advances in engineering—across differences of race, ethnicity, gender, and abilities. Instructional materials have a broad range of images and stories of who does and has done STEM endeavors in our society (through inclusive storylines, phenomena, sustained examples), and highlight the broad range of purposes for STEM endeavors (focusing sense-making on community projects, civic engagement, personal and family pursuits, justice projects, and 21st century global challenges and decision-making, not just STEM-related career possibilities). Design teams consider whose interests are being served by the images of STEM endeavors represented in instructional materials and prioritize the interests of underserved communities.

2.1.1. Instructional materials acknowledge the specific contributions of members from multiple communities to scientific and technological enterprises related to the topic, practices, and knowledge involved. These accounts are substantial, accurate, and respectful to the originating work and community. Both pictorial and descriptive images of STEM endeavors include diverse images in historical, contemporary, and future-focused terms as appropriate. The diversity of STEM endeavors of cultural communities are not inappropriately portrayed only as efforts from the past and make visible the diverse forms of STEM efforts that are currently unfolding and evolving.

2.1.2. Cultural and gender diversity is integrated into lessons by carefully weaving together subject matter, corresponding sense-making activities, and images with relevant sociocultural contexts that recognize the scientific and technological contributions of members from various cultural backgrounds. For example, instructional materials include and clearly highlight the efforts of scientists of all gender identities. Learning experiences are designed to promote a deeper sense of global community, agency, and social responsibility, rather than using phenomena, settings, or examples that primarily center on the activities or interests of the dominant U.S. culture.

2.1.3. Topics, concepts, and practices within units are related to the backgrounds of students by recognizing that all learners belong to multiple cultural communities that share different practices, purposes, ways of interacting, and approaches to conceptualizing and engaging with the world. Students are able to "see themselves" in the scientific endeavor—as represented through instructional materials—in order for them to feel comfortable engaging in science learning meaningfully.

2.1.4. The dynamic and variable nature of cultural groups is highlighted, including the inherent variations and regularities in cultural practices and values, and how these may change over time. Instructional materials avoid essentializing the activities and qualities of cultural groups and actively work against narrow and uniform (formulaic) ways that science is conducted (for example, by highlighting different forms of argumentation and explanation). Instructional materials do not assume that all learners from a given cultural community engage in similar sense-making practices, or that certain cultural communities are homogeneous and stable over time.

2.2 Learning experiences focus on youth relevance and community purpose.

Building on the vision of *A Framework for K-12 Science Education*, instructional materials relate to the interests, identities, and experiences of students and the goals and needs of their communities. Instructional materials create opportunities for instruction to be guided by *cultural formative assessment* strategies and to leverage local funds of knowledge.

2.2.1. Instructional materials create opportunities for teachers to engage in cultural formative assessment, eliciting and instructionally responding to their students' prior knowledge, interests, and identities. At least twice within each unit, after students develop an understanding of an important science idea, a self-documentation instructional technique is used to help students see how the focal science ideas they have learned about relate to everyday phenomena of their lives (for example, ask students to take pictures of phenomena in their life that relate to Newton's second law, and then make sense of the resulting collection together).

2.2.2. Instructional materials make explicit the importance of identifying the dynamic everyday practices and concerns in the students' communities that can be meaningfully related to classroom science and engineering investigations. Units explore how anchor or investigative phenomena relate to the interests and practices of the local community or to a shared global concern. The leading activity of units are personally meaningful phenomena, not abstract science ideas, and are sometimes introduced through a *cultural launch* that locates the anchor phenomena in a context of the community.

2.2.3. Cultural formative assessments support teachers in building on students' prior interests, identities, and experiences. For example, developing expertise or interest of a student might relate to the knowledge work in a unit, and students can be positioned in a teacher-like role in the classroom. At least three times each year students should be able to relate science ideas or practices they are learning about and put them into some type of action (such as working as an individual or in a small group to develop a public service announcement that applies science ideas to a specific topic or practice, or working in a small group on a design project that applies science ideas to an authentic problem).

2.2.4. Instructional materials include opportunities for teachers to support students to engage in community endeavors as part of their science class. Each year there are at least two sustained, culturally meaningful science investigations that occur in the context of the local community (such as a field investigation, design project, or local data collection at school site). At least two middle school units focus on anchor phenomena that can be meaningfully focused in relation to the community (that is, not all units have a fully "pre-packaged" anchor phenomena). This should include taking a place-based science education approach.

2.2.5. Instructional materials include opportunities for students to develop new science-related interests and to learn how they relate to social pursuits in the world. Within each unit, students are given time to document, reflect on, and explore their developing science-related interests, and they are supported to further explore those interests (for example, by talking with an expert or researching different endeavors online or at the library).

2.2.6. Teachers are guided in relating science to the histories, current priorities, and aspirational futures of communities, especially those of local indigenous communities in conjunction with their recognized rights and other groups owed an education debt. This can shape the framing and relevancy of science ideas and practices, the pedagogical approach, the languages used in instruction, and the experts brought in to support science learning.

2.3 Equitable sense-making is supported in the science classroom.

Creating equitable learning opportunities depends critically on students' ideas and reasoning as being connected to science, as opposed to being off topic, or, disruptive. Instructional materials enable teachers to recognize and leverage diverse assets and perspectives students bring for making sense of phenomena, and broaden what counts as competency to include everyday and professional forms. Instructional materials actively work against reductive accounts of proficiency (such as privileging prestige English in rubrics, or culturally narrow images of the science and engineering practices). They scaffold multiple forms of practice engagements and identify as well as leverage students' sense-making repertoires, rather than an idealized, dominant form.

2.3.1. Instructional materials cultivate an equitable learning community in the classroom by engaging students in activities that promote trusting and caring relationships, a shared understanding of the cultural diversity of its members, and equity in all sense-making. Each unit includes a community building exercise or activity that relates to the focus of the unit. Instructional materials emphasize the importance of developing and maintaining equitable learning experiences, particularly by interrogating participation, and by promoting social norms that support safe and fair participation while interrupting cultural norms or stereotypes that could make science experiences feel unwelcome to students who might otherwise feel disenfranchised from science (for example, feeling like someone who is not intelligent enough to think like a scientists, who cannot do the relevant math, or who cannot share their thinking).

2.3.2. Units are designed to ensure that all students are positioned to intellectually engage throughout all collaborative sense-making. Instructional materials highlight the importance of not putting students into set roles that are less intellectually engaging, like "materials manager," and instead use a range of intellectual roles associated with the collaborative learning process (for example, idea connector, causal checker, evidence wrangler, and relevance hunter).

2.3.3. Activities allow for teachers to notice and leverage students' diverse sense-making contributions and connect them to the science and engineering practices involved in an investigation. These contributions can relate to styles of speaking or writing, ways of observing and interpreting, forms of reasoning, uses of gestures or movements, or diagrams and other forms of expression. Instructional materials create opportunities for instruction to make room for these different kinds of contributions to all sense-making activities, rather than expecting students to contribute in narrow or prescribed ways. Teachers receive instructional guidance to leverage the specific contributions of individual students and make direct connections to science, rather than lightly polling (or "popcorning") across the classroom community.

2.3.4. Teachers are guided in highlighting how students' community histories, values, and practices contribute to scientific understanding and problem solving. Classes explore how students' community histories, values, and practices contribute to scientific understanding and problem solving related to the unit investigation.

2.3.5. Instructional materials include a broad representation of how various communities leverage their ways of knowing, ways of talking, and ways of seeing the work for making sense of natural phenomena and solving problems, and avoid causing epistemic injury by communicating that science and engineering practices occur only one way.

2.3.6. Teachers are guided in using embedded cognitive formative assessments to surface and instructionally respond to students' facets of thinking (the full range of student's ideas about a topic or concept) throughout the sense-making process. Students develop these facets of thinking as they experience and make sense of the natural world. Teachers are guided on how to respond to specific ideas from an asset-based perspective (what is appreciated, what is concerning), allowing them to recognize the richness in students' reasoning and to support students to refine their ideas in a constructive and respectful manner. Facet-based rubrics that account for the diversity of student's typical thinking are included for assessments integrated in lessons around the learning of difficult concepts. Rubrics do not focus on single-scale learning progressions or only on identifying students' misconceptions.

2.3.7. Instructional materials create opportunities for students to engage in engineering design practices in culturally meaningful ways, particularly by leveraging students' everyday experiences and contextualizing design projects to be locally relevant.

2.3.8. Teachers are guided in understanding the importance of navigating within and across multiple ways of making sense of the natural world, such as instructionally centering on the *Indigenous Ways of Knowing and Being*.

2.4 Participation and learning of multilingual learners are supported.

In order to support English language learners, instructional materials are designed to support equitable participation in science and engineering practices, in ways that are culturally sustaining; leverage students' full linguistic repertoires, such as multiple languages and registers; and value and promote multi-modal performances beyond written or spoken forms of expression. Supporting the equitable participation and learning of English language learners and all students requires new understandings of the language affordances and demands inherent in science learning. Additionally, this shift requires understanding new strategies for building on the lived experiences and linguistic resources that all students bring to the science classroom. For further guidance on addressing the needs of multilingual learners, refer to *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives.*

Multilingual students are often referred to as 'English Language Learners', but instructional materials should use the term "emerging multilingual students" to acknowledge and value these students' bi-/multilingualism, bi-/multiculturalism, and highlight that they have a right to learn science content beyond developing English fluency.

2.4.1. Instructional materials clearly state that cultural and professional communities have *specialized discursive practices* that allow community members participate in meaning-making activities. Specifically, they explain that science and engineering have developed specialized discursive practices that help their members make sense of natural phenomena and solve problems. At least three times each year, students have opportunities to identify the similarities and differences between familiar everyday ways of communicating and the specialized ways of communicating of science and engineering (for example, an activity that has students identify the similarities and differences between forms of evidence-based argumentation and forms of opinion-based argumentation).

Units make the case for why specialized ways of talking are productive for sense-making, and should not delegitimize students' everyday ways of talking.

2.4.2. Instructional materials clearly state that cultural and professional communities have *specialized languages* (registers) that help community members share their ideas and collaboratively make meaning. Specifically, they explain that it is normal for people to switch or intertwine registers from different contexts when engaging in sense-making activities. Every unit creates opportunities for students to engage in register switching along the continuum of everyday language and the specialized language of science and engineering, according to what they find most useful. Units present content and create opportunities for teachers and students to share ideas by leveraging linguistic resources along the continuum of everyday language and specialized language. Activities do not bar students from using everyday language for their sense-making and communication, especially when this can be a powerful tool for equitable participation. The continuum between everyday and specialized language is available for students to choose from when sharing their ideas and reasoning.

2.4.3. Instructional materials recognize and center students' multilingual and multicultural experiences, highlighting how people around the world engage in science and engineering practices in multiple languages besides English. Units use translanguaging approaches that create opportunities for students to engage in science and engineering practices while fluidly leveraging the multiple languages they speak. Specifically, every unit creates opportunities for teachers to identify, promote, and use the various linguistic resources multilingual students marshal when making sense of natural phenomena or solving problems. For example, an activity where students develop and present forms of evidence-based explanations using their heritage languages or blending the multiple languages they speak. Units do not promote (or connote) English-only instruction, especially in multilingual classrooms.

2.4.4. Activities are included that create opportunities for teachers to leverage what they know about specific students' multilingual and multicultural experiences to help students make personal connections to science content knowledge. Specifically, instructional materials allow teachers to gather information to encourage students to describe times and places where they see the science they are learning in school being used outside of school, and include supports (such as prompts) for teachers to include those understandings into their instructional planning.

2.4.5. Instructional materials focus on more than text-based sense-making by promoting multimodal communication to support students in making meaning of phenomena or address design challenges. Each unit leverages multimodal and intertextual approaches to highlight and make visible key ideas. For example, every unit has opportunities for teachers and students to share ideas by using modalities that go beyond speech and written text, such as graphical representations, gestures, onomatopoeias, and embodied representations of key concepts and processes. Instructional materials do not bar students from using multiple modalities for meaning-making, especially when this is a powerful tool for equitable participation. Students are able to use both linguistic resources and multiple modalities when sharing their ideas and reasoning.

2.4.6. Activities are organized in ways that create opportunities for multilingual students to engage in meaningful accountable talk, by emphasizing socially safe and relevant activity structures (such as small group work before whole class discussions) and by providing a range of scaffolds for multilingual students to find their way into discussions. For example, at least three times in every unit students have the opportunity to engage in think-pair-share or "idea coaching" structures, and are provided with modalities to support all students in engaging with and making sense of each other's ideas.

2.5 Participation and Learning of Special Education students are supported.

Instructional materials are designed to follow principles of the Universal Design for Learning: provide students with multiple means of engagement, representation, and expression; leverage students' sense-making repertoires to support three-dimensional learning; and support peer interactions that enable active engagement in investigation-based science learning. Additionally, they create opportunities for students with learning needs to develop self-regulation, self-determination, and agency in order to meaningfully participate in sense-making activities. From this perspective, equitable instructional materials are designed to reduce barriers that hinder participation and offer students multiple opportunities to engage in deep sense-making of the natural and designed worlds; instructional materials do not assume that students themselves require modifications and adaptations to meet learning goals. Instructional materials support the creation of learning environments that are more usable, accessible, safer, and healthier in response to the needs of an increasingly diverse student body, which can be achieved in part by avoiding ableist language and depictions of learners.

Print and web-based materials will be designed to be products that offer the maximum flexibility of user experience for all readers, allowing the content to be accessed and manipulated with ease by those with or without disabilities. Specifically, instructional materials should account for the following requirements: (1) Structurally-tagged content; (2) Text to speech (TTS) capability; (3) Alternative background colors and controllable line spacing; (4) US Department of Education Standards; and (5) Web Content Accessibility Guidelines (WCAG).

2.5.1. Instructional materials do not include ableist language that could be offensive (such as abnormal, crazy, loony, or victim) and are based on the use of these resources from the National Center for Disability and Journalism for more information: *Terms to Avoid When Writing About Disability* and *Disability Language Style Guide*.

2.5.2. Instructional materials provide multiple means of engagement to encourage purposeful and motivated three-dimensional science learning:

a. Every unit recruits students' interest by optimizing individual choice throughout the learning process while engaging students in relevant, rigorous, and meaningful sense-making. Individual choice extends beyond students choosing their own topic of study or investigation method and includes choices for how students will meet classroom objectives, such as level of perceived challenge of an activity, modes or tools for expressing themselves, and sequence or timing for completing activities. For example, students may be given the choice of different methods to express themselves (such as verbal responses, drawing, acting, or movement demonstration) when presenting information or understanding of what they have learned.

b. Instructional materials guide teachers to organize learning environments in ways that are physically navigable to all students. They sustain learner effort and persistence by making goals and objectives clear, fostering peer collaboration, and building community relationships. Moreover, instructional materials anticipate and list the barriers required equipment may present to students and suggest alternative materials and/or setups.

c. Lessons support students' self-regulation and self-assessment and create opportunities for teachers to provide performance-based feedback (for example, self-monitoring scaffolds where students can compare their engagement and participation to the expectations of the classroom and unit). Additionally, lessons demonstrate how professional scientists and engineers self-monitor their experiences of and self-regulate their responses to challenges that arise during group-work, during the iterative processes of design thinking, and/or planning and implementing investigations.

d. Instructional materials guide teachers with general supports and scaffolds that can be used across lessons or units. Teachers can tweak the general supports to make them better match the lesson (content, types of activities) if desired. For example, providing a "visual task schedule" to help students learn and monitor classroom routines or the steps for completing specific academic tasks that includes visual icons and text for each step in the routine or task. Students refer to the visual schedule and can check off when they have completed the steps in the routine or remove the picture icon from the task schedule.

2.5.3. Instructional materials provide multiple means of representing information and expectations to make the materials comprehensible to learners with learning needs. Every unit supports students to reflect and build on their prior knowledge, and construct generalizable explanations and models.

2.5.4. Instructional materials provide multiple opportunities for students to express their understanding and reasoning. Every unit includes multiple tools that support students' engagement with activities and sense-making (such as investigation materials or assistive technologies), leverages multiple modalities for communicating content and expectations, and provides opportunities for students to express their understanding through recruiting multiple modalities (such as drawings or gestures). Instructional materials make it clear that providing multiple means for expression is categorically different from so-called "learning styles," arbitrary categories such as "visual learner" and "kinesthetic learner," which are not scientifically valid and yet prevalent in discussions about learning needs.

2.5.5. Instructional materials create opportunities for students to actively participate in group work, and support teachers to set clear goals for activity-driven learning, as well as scaffolds to self-regulate progress in groups and promote students' agency. Every unit reinforces a positive group-work culture by encouraging students to identify their resources that can strengthen their group, as well as systems to ensure that all students are actively participating in sense-making. Units include multidimensional, multi-level activities that require the work of all group members to accomplish.

3–Assessment to Inform Teaching and Learning

According to the National Taskforce for Assessment Education, "assessment is the process of gathering evidence of student learning to inform education-related decisions. The impact of decisions depends on the quality of the evidence gathered, which in turn, depends on the quality of the assessment, and associated practices, used to gather it."

Assessment design is considered in tandem with instructional materials design so that the evidence gathered through assessment can inform instruction and learning. There are well-designed assessment opportunities that support evidence gathering for a wide range of purposes, including formative assessment conversations that occur during instruction, embedded tasks with rubrics that support the interpretation and use of student ideas to inform instruction, and summative assessments. Assessment is a process that involves students in analyzing their own and their peers' ideas and considering how to use those ideas as they move forward in making sense of phenomena. Teachers are guided in collecting and using assessment evidence to assist all students in their learning so that both teachers and students benefit from the process. Due to the different assessment formats used by different states, assessments do not attempt to prepare students for a specific type of large-scale summative state-level test.

3.1 A systems approach is used to design assessments.

Instructional materials use a systems approach to assessment that takes multiple purposes of assessments into account, and ensures that all assessment opportunities coherently provide multiple pieces of evidence that can support claims about what students know and can do in science. The format for the different types of assessments throughout each unit is matched to the assessment purposes. Assessments are sensitive to students' learning experiences, embedded in instruction, are seen by students as connected to what and how they learned, and respond to the instructional features of the materials.

3.1.1. Each unit includes an *incoming formative assessment task or discussion* to determine what incoming ideas and experiences students bring to the unit. These incoming formative tasks are linked to the unit learning goals and phenomenon, design problem, or driving question. Teacher materials have information for how to elicit students' ideas and use them as resources to inform future instruction.

3.1.2. Activities include *informal formative assessment opportunities* to determine whether students are building understanding. Teacher materials include information on how to interpret student ideas to provide feedback and make instructional decisions.

3.1.3. Instructional materials include *key formative (or mini-summative) embedded assessment* tasks to be used as checkpoints at critical junctures in the unit. Teacher materials include a rubric on how to provide feedback and make instructional decisions based on results of these tasks.

3.1.4. Instructional materials include *end of unit summative assessment* (for example, a performance task) to determine whether students met the learning goals for the whole unit that uses a closely related (but separate from the unit) phenomenon, problem, or context.

3.2 Assessments are aligned to three-dimensional learning goals.

Assessment opportunities examine students' performance of scientific and engineering practices in the context of crosscutting concepts and disciplinary core ideas. The multiple assessment opportunities implemented in a unit provide evidence of students' building ability with all three dimensions.

3.2.1. All assessment opportunities ask students to integrate disciplinary core ideas, science and engineering practices, and crosscutting concepts to investigate and make sense of phenomena and solve problems, and occur in multiple modalities and include multimodal representations (such as words, images, diagrams).

3.2.2. Incoming formative assessment tasks ask students to use their incoming ideas, experiences, and cultural ways of knowing to engage with the unit phenomenon or problem, and appropriately scaffold engagement with disciplinary core ideas, science and engineering practices, and crosscutting concepts. Formative assessment tasks support teachers to consider how students' background knowledge, cultural ways of knowing, and prior experiences can serve as resources for learning.

3.2.3. Informal formative assessment opportunities are aligned to three-dimensional learning goals of the particular activity or lesson, based on a bundle of performance expectations, and may scaffold aspects of the three dimensions.

3.2.4. Embedded assessment tasks are aligned to learning goals to that point in the unit, based on a bundle of performance expectations, and may scaffold aspects of the three dimensions.

3.2.5. End of unit summative assessment tasks use detailed scenarios involving phenomena and problems, accompanied by one or more prompts, and have multiple components (such as a set of interrelated questions) that yield evidence of three-dimensional learning. Individual prompts and tasks as a whole require students to demonstrate and use each targeted dimension appropriately, use multiple dimensions together, and use three-dimensional performances to sense-make (reason with scientific and engineering evidence, models, and scientific principles). End of unit assessments require at (or below) grade-level English language arts and mathematics competencies, and use the evidence statements from Achieve and the performance expectation assessment boundaries and clarification statements, as well as the progressions, described in the appendices and prompts in *STEM Teaching Tools*.

3.3 Assessments are designed to allow for a range of student responses.

Assessment opportunities anticipate the wide range of backgrounds, experiences, resources, questions, and ideas that students bring to the science classroom. Assessment tasks are dexterous enough to capture students' background knowledge and initial ideas at the start of the unit as well as how these ideas develop as students integrate information and evidence from activities during the course of the unit. To the extent possible, assessments embedded with instructional materials allow students the option of expressing their emergent understanding in a language and format in which they are most comfortable, and offer students choices in how they respond (for example, orally, in writing, or through a diagram).

Formative assessment opportunities allow for a range of student ideas to be expressed so that the teacher and students can use those ideas to shape subsequent teaching and learning. Teachers are advised that providing "correct" responses right away undermines the instructional model. Instead, and are guided to provide students with time to make sense of ideas themselves. Formative assessment opportunities allow students from a wide range of backgrounds to participate. Summative assessment opportunities allow for all students to demonstrate where they are in their progression toward the learning goals.

3.3.1. All assessment opportunities are appropriate for diverse populations of students. They have gone through a bias and sensitivity review for all students, including female students, economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, students with limited English language proficiency, and students in alternative education, and include diverse representations of scientists, engineers, phenomena, and problems to be solved.

3.3.2. Incoming formative assessment tasks incorporate multiple modalities for students' to share complete, partial, or incomplete ideas, using the process described by the F*ormative Assessment for Students and Teachers State Collaborative on Assessment and Student Standards* (FAST SCASS).

3.3.3. Informal formative assessment opportunities follow the FAST SCASS process that incorporates multiple modalities for students' to share complete, partial, or incomplete ideas. They can be discussion-based, and use strategies to allow all students to make their thinking visible (such as providing thinking time to rehearse responses). Informal formative assessments encourage students to listen to one another, compare and evaluate competing ideas, and merge ideas to construct new explanations. They invite students to revise their ideas based on new information or evidence and include opportunities for teachers to ask follow-up questions or revoice students' ideas.

3.3.4. Embedded assessment tasks provide opportunities for students to engage with self- and peer-assessment and critique, and provide teachers with actionable information, data, and evidence for planning instructional sequences.

3.3.5. End of unit summative assessments suggest modifications or scaffolding for English language learners and special education students, and include multiple task formats (multiple choice, true or false, short answer, and model development).

3.4 Teachers are guided in interpreting and using student ideas.

Assessments, and ways of interpreting those assessments, help teachers understand students' current understanding on a range of less to more sophisticated. Instructional materials include assessments and educative materials that support a *learning progressions stance,* meaning that student ideas are not considered simply right or wrong, but rather as ideas that can be used to support a progression toward higher levels of understanding. Information comes from field-testing directly as a way to capture authentic student experience and learning.

3.4.1. All assessment opportunities provide teachers with examples of student ideas that may emerge and how to use those ideas as resources for instruction. They provide resources for supporting student use of feedback and information to inform their learning.

3.4.2. Formative assessment tasks include possible student responses and strategies for using responses to drive further instruction (for example, driving question board, sticky notes, or talk moves).

3.4.3. Informal formative assessment opportunities include options for talk moves or instructional tasks that help support students on different learning progressions (or with different facets of understanding), including examples of student responses.

3.4.4. Embedded assessment tasks include learning-progression-based or asset-based rubrics and teacher materials that help teachers identify the range of different student ideas and how to score students using a rubric. They provide guides for peer- and self-assessment that align with the learning progression or rubric.

3.4.5. End of unit summative assessments include rubrics for scoring and examples of student responses for each item and rubric level, and provide support to teachers for guiding students toward more sophisticated ideas.

4–Designing Educative Features

The goal of educative instructional materials is to support teacher learning as well as student learning. Educative features are the elements that are added to the base materials that are explicitly intended to promote teacher learning. OpenSciEd's educative features are designed to support the wide range of teachers who use the instructional materials and to help teachers find the support they need, when they need it. The educative features a teacher accesses their first year using the materials will likely be different from those accessed in future years when the material is more familiar.

4.1 Instructional materials support equitable science teaching.

All students deserve to experience rigorous and consequential science learning. By attending to issues of equity explicitly, educative features within science materials work to promote a more just, equitable, and inclusive society.

4.1.1. Lessons incorporate high leverage teaching strategies and best practices to support teachers to meet the needs of diverse learners such as English language learners, economically disadvantaged students, students from groups traditionally underrepresented in science, students from non-dominant communities, students with special needs, students who need extra challenge, and other students who may need particular support. These can be customized for specific locations or contexts.

4.1.2. Teachers are guided to adapt lessons as appropriate to incorporate local examples and make other changes that maintain rigor, but increase local relevancy (for example, suggestions in instructional sequence or narrative descriptions).

4.1.3. Instructional materials support English language learner teachers, and all teachers, by providing student-friendly definitions, connections to cognate words, and other language supports that have been documented to support language learners.

4.1.4. Instructional materials support teachers to help prompt cultural connections, including both ideas that can be emphasized as connections as well as what should be avoided. They provide teachers with strategies that help recognize students' diverse ideas as resources on which to build (for example, sample student work, suggestions in instructional sequences, rubrics with sample teacher comments, or vignettes of a student story).

4.1.5. Instructional materials support teachers of students with special needs by providing suggestions for potential modifications (such as changes to a specific expectation) and accommodations (such as provision of additional scaffolding) that could be made (for example, suggestions in instructional sequence, call-out boxes, or videos of enactments).

4.2 Teachers are guided in teaching toward a Next Generation Science vision.

Instructional materials are aligned to the goal of moving classrooms toward the intention and vision of *A Framework for K-12 Science Education* and the *Next Generation Science Standards*, with instruction oriented around phenomena and problems and aimed toward rigorous and consequential science learning for every student.

4.2.1. Teachers are guided in understanding that each of the three dimensions requires both subject matter knowledge and pedagogical content knowledge.

a. At the unit level, teachers are provided links to resources that support understanding each dimension, which may include links to specific *Framework* sections or appendices, or to *National Science Teachers Association* webinars. These resources help teachers understand each science practice, crosscutting concept, and disciplinary core idea (with examples and non-examples), and how practices differ from process skills, why each element is a fundamental element of the NGSS vision, and what the connections are (how practices work together, how crosscutting concepts thread across disciplines, and how disciplinary core ideas connect to one another).

b. At the lesson level, additional guidance is provided to help teachers recognize specifically where each dimension is at play in the lesson plan, support students in engaging in each relevant practice, seeing the crosscutting concepts within and across units, developing disciplinary core ideas through engaging in practices, and anticipate the challenges students are likely to face when engaging in each relevant practice or developing an understanding of each relevant crosscutting concept or disciplinary core idea.

4.2.2. Teachers are guided in understanding what constitutes a phenomenon, recognizing what makes a phenomenon productive for exploration, and making the shift from learning about ideas to figuring out how phenomena work, including helping them see what this looks like when students do it (for example, graphic organizers or links to outside readings or videos).

4.2.3. Teachers are guided in developing a set of high-leverage science teaching practices, such as leading a sense-making discussion, supporting small group work in investigations, eliciting students' ideas, developing classroom norms for discourse and work in the disciplines of science, and supporting students' explanation and argumentation (for example, videos of enactments, narrative descriptions of enactments, or links to outside readings or resources). Instructional materials provide lesson-specific supports including discussion questions, tasks, or problems that a teacher can use to elicit students' ideas; student roles, discourse norms, and accountability mechanisms for small group work in investigations; and discourse moves and scaffolds. They provide classroom-level supports, including guidance on developing discussion norms, routines, and protocols for explanation, modeling, and argumentation, and suggestions (such as posters and table cards) that can support students in developing and implementing classroom norms for discourse and work in the disciplines of science.

4.2.4. Teachers are guided in their use of assessments. Instructional materials provide supports for engaging in a range of assessment forms, including informal, formative, and end of unit summative, including rubrics with sample teacher comments, sample student work, call-out text boxes, as well as support to promote understanding of how each form contributes to students' science learning, and strategies for addressing the practical challenges of assessing many students in a timely manner.

4.2.5. Instructional materials include guidance for making productive adaptations based on the needs of the class that make instruction more accessible (such as a continuum of scaffolding), paying particular attention to scaffolding students' early experiences with science practices. They help teachers identify appropriate support depending on their students' experiences with three-dimensional learning in elementary grades.

4.2.6. Instructional materials help teachers see how each of the three dimensions build coherently over time with the materials, and provide strategies for helping students see where they have been and where they are going (for example, a poster of a unit-level model tracker illustrating how the class ideas are evolving over time to address the overarching phenomena, or a map with a "you are here" indicator that the teacher can move).

4.3 Instructional materials support teachers and students to spend more time engaged in teaching and learning.

Instructional materials encourage classrooms where effective management supports students in rigorous and consequential learning. Effective management means teachers and students spend less time on non-instructional issues and more time engaging in teaching and learning.

4.3.1. Teacher materials support effective preparation, classroom management (including grouping of students), materials management (obtaining, organizing, distributing, and cleaning up), space organization, and development of productive classroom norms. For each lesson, they provide photos, drawings, or videos of classrooms or artifacts that illustrate effective preparation or management strategies. Teacher materials provide alternatives for teachers without a home classroom (such as cart-based materials management) or with other particular needs (for example, via call-out boxes, narratives, or videos).

4.3.2. Teacher materials help teachers anticipate likely lesson pitfalls and how they might be able to either prevent or recover from them (for example, via narratives).

4.3.3. Teacher materials provide guidance for the effective use of technology (such as simulations or websites) for different technology setups (single computer classroom, one-to-one classrooms, shared computers).

4.3.4. Teacher materials support teachers in communicating with families and caregivers, administrators, and other stakeholders (for example, by providing sample text for newsletters describing the intent of the OpenSciEd materials, or descriptions of projects or assignments that will require time or resources from home).

4.3.5. Where appropriate, teacher materials provide suggestions for effective opportunities for getting outside the classroom (for example, park, zoo, aquarium, pond, woods, or museum) as well as options for assignments and activities for such trips and scripts about the value of the trips that teachers can use when seeking funding and approval for field trips.

4.4 Teachers are guided in the use of the instructional materials.

Instructional materials are designed for effective use, particularly designed so teachers can experience success early on, and then dig in deeper to continue learning as they use the materials over time. Educative features help to guide that learning process.

4.4.1. Teacher materials include guidance on how instruction can be differentiated, and include tools and alternative activities that teachers can use selectively depending on classroom needs, school or community contexts, or district priorities.

4.4.2. The front matter of units and program-level materials provides guidance to help teachers recognize and use different aspects of the instructional materials. They present educative features in a user-friendly format, and suggest that teachers may focus on working on one or two elements of their instruction at a time (rather than trying to attend to all of the educative features included in the materials).

4.4.3. Teacher materials inspire teachers and support them in realizing that engaging in this work will have bumps in the road, but that those challenges can be productive for teachers' own learning and can support future change (for example, via narrative descriptions of enactments, or videos of enactments or interviews with teachers).

4.4.4. Where appropriate, teacher materials provide recommendations for resources for further exploration (such as readings, videos, simulations, professional development opportunities, graduate coursework), recommend that teachers join professional learning communities or engage in other collaboration with colleagues, and help teachers see connections to common pedagogical approaches and common school-based rituals (such as science fairs or exhibition nights) that can be leveraged for and integrated with the intentions of NGSS.

4.5 Instructional materials are effective and efficient.

Instructional materials effectively and efficiently support teacher learning. Every student deserves a teacher who understands and is able to use new instructional materials that support current reforms. Teacher materials are developed based on research about effective instructional design for supporting teacher learning.

4.5.1. Teacher materials include rationales for the design of lessons and units to give teachers confidence in implementing instructional practices that differ from their prior teaching and learning experiences. They are selective about what to include in teacher materials and how, so the materials do not become too lengthy.

4.5.2. Instructional materials anticipate that teachers will adapt them and make suggestions that can help teachers make productive adaptations, rather than assuming teachers will follow lesson plans exactly.

4.5.3. Teacher materials recognize that teacher learning is a process and provide recommendations for changes to make, or techniques to try over time, to build complexity. Educative features are worded positively (for example, “allow students to struggle”) and acknowledge the variability among teachers and recognize that no teacher will use all of the educative features.

4.5.4. Teacher materials use a range of forms to support teachers’ different needs and avoid using extensive expository text. Some support is not directly grounded in teachers’ practice and can be used sparingly (such as call-out text boxes with definitions or information, links to outside readings, videos, or other resources, and graphic organizers). Other support can be directly connected to and used in teachers’ practice (for example, rubrics with sample teacher comments, sample student work, videos of enactments of specific lesson portions, narrative descriptions of enactments, videos of interviews with teachers, student-friendly definitions, or suggestions within an instructional sequence).

5–Asking Questions and Defining Problems

A Framework for K-12 Science Education states about the practice of *Asking Questions* that "Science begins with a question about a phenomenon and seeks to develop theories that can provide explanatory answers to such questions," and about the practice of *Defining Problems* that "Engineering begins with a problem, need, or desire that suggests an engineering problem that needs to be solved." Therefore, a basic practice of the scientist is "formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered," while engineers "ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints" as part of the core engineering practice.

An important assumption in this description is that, if students are the ones participating in these practices, then it should be *students' questions* about phenomena or engineering problems that drive their activity—*and their learning*—forward. It should be their curiosities and interests that motivate their learning through the cycles of investigation, analysis, modeling, and argumentation that come out of this science and engineering practice. NGSS-aligned instructional materials explicitly support the practice of asking the following five types of questions:

a. *Wonderment questions* draw out the awe and wonder of a phenomenon, and highlight areas of puzzlement or weirdness. These questions support students' curiosity and motivation for learning science, and are especially important in establishing the driving phenomenon or articulating an engineering problem.
b. *Classroom discourse questions* that students ask of each other help support productive disciplinary discussions. These instructional materials draw on Michaels & O'Connor's *Conceptualizing Talk Moves as Tools* to support academically productive discourse as a framework for supporting these questions.
c. *Investigation questions* guide the design of a specific investigation. This also includes questions that support the examination and evaluation of criteria and constraints of engineering design solutions. These are the "empirically answerable" questions emphasized in most existing literature about "Asking Questions".

d. *Procedural or design questions* are about measurement or methods. These questions often arise while doing investigations and are often taken for granted, but need to be asked and answered explicitly in order to carry out investigations in science, design a solution during an engineering process, or to evaluate existing data.
e. *Epistemic questions* are about reasons for pursuing specific questions, what we already know and don't know, and the design and conceptual steps we need to take next and why. This also includes questions evaluating what criteria and constraints are desirable for a particular engineering design challenge. Though students are not solely responsible for asking these questions early on, instructional materials support students in taking increasing ownership over both asking and answering these kinds of questions.

These types of questions are related and interdependent: wonderment questions evolve gradually, perhaps over the course of several lessons, to investigation questions; epistemic questions mediate the evolution of wonderment questions; procedural and design questions may arise from the investigation process, and new wonderment questions may arise from the results of an experiment. This evolutionary process—a continual cycling of refining and broadening—is only made possible through sophisticated use of classroom discourse questions by both teachers and students.

These design specifications are organized around three foundational design categories: *coherence* (sequencing activities that simultaneously position students' questions and questioning practices as driving the learning and ensure that particular bundles of performance expectations will be met), *pedagogical scaffolds and supports* (developing a classroom culture that supports students in asking questions and defining engineering challenges), and *student scaffolds and supports* (providing support for students in asking questions, defining engineering challenges, and increasing their agency over time).

5.1 Student questions and identification of problems drive instruction.

Central to the vision of *A Framework for K-12 Science Education* and the NGSS is that posing questions and identifying problems is the basis of science and engineering, and that engagement in both should be a primary feature of classroom learning. Student questioning and ideas are the foundation of and driver of science instruction; student problem scoping and understanding of the design challenge are the foundation and driver of the engineering process. In addition, students need to be provided with opportunities to apply their understanding and science and engineering practices to answer their questions and design solutions to identified problems.

As classroom instruction shifts to become student-centered and consequently student question-focused, the need for a supportive classroom culture in which students are encouraged to ask questions and define problems become key. Within such an environment, different types of questions and problems can be identified and used to develop student understanding of core science concepts to explain of real-world phenomena. OpenSciEd instructional materials both follow students' questions and meet the identified learning goals in coherent ways.

5.1.1 Instructional materials connect students' everyday knowledge to the wonderment of the world and school science and to the need to ask questions and define problems. Materials use phenomena that allow for links between students' questions, desired science content knowledge, and identified bundles of performance expectations.

5.1.2. Teacher materials are structured to anticipate the questions students will ask about a phenomenon or problem and to connect conceptual and epistemic ideas using students' questions, specific investigations, and lesson-level learning performances. They create a coherent roadmap from the students' perspective of a developed sequence of instructional activities.

5.1.3. Activities are included that make explicit the importance of students generating their own questions around scientific phenomenon in science instruction (such as a driving question board), and the identification of the scope of the problems to solve during the engineering process.

5.1.4. Instructional materials emphasize and discuss the many reasons scientists have for asking questions and engineers for identifying and defining problems, the different types of questions, and the purpose of asking these different questions throughout the unit for both science and engineering.

5.1.5. Students are supported to first develop their own individual questions prior to group discussions and whole-class consensus building. Instructional materials provide opportunities and scaffolds for students to ask different types of questions and support their understanding of the differences between them and the specific context for each question. In the engineering process, they provide opportunities and scaffolds for students to identify and define problems.

5.1.6. Instructional materials include strategies to support students in asking questions that direct their learning, and to create opportunities for students to iterate on their design solutions in meaningful ways, on multiple occasions throughout the year.

5.2 Students understand that science and engineering involve unresolved questions or problems, and instructional materials support students in navigating this uncertainty.

OpenSciEd seeks to normalize the idea that science and engineering involve unresolved questions or problems, and that not knowing the answer or solution to a question or problem can be productive and drive the learning process. Instructional materials support the goal of creating learning environments that embrace students' scientific and engineering uncertainty, and willingness to accept not knowing the answer to a question that they are asking or a problem that they are defining. Readiness to accept and embrace uncertainty by both teachers and students is a prerequisite condition for student-centered and open-ended activities. Teacher materials guide teachers in creating learning environments that support and scaffold students in navigating uncertainty in the learning process.

5.2.1. Instructional materials explicitly indicate the multiple ways that students assume more and more responsibility over their own learning (within a lesson, a unit, and across a year) around asking questions or defining problems.

5.2.2. Teacher materials provide explicit supports for teachers to guide students to assume more and more responsibility around asking questions and defining and scoping problems.

5.2.3. Activities afford multiple opportunities for divergent and convergent thinking and support a diversity of questions across the unit around science phenomena and engineering problems for which we might not know the answers to.

5.2.4. Engineering tasks are designed to support student questioning so that they lead to investigations of the underlying science ideas. Teachers and materials need to support students shift in thinking from *"will this work"* to *"why does this work"* in order address the disciplinary core ideas.

5.2.5. Teacher materials help teachers develop a safe and supportive space for students' uncertainty around science and engineering concepts, and focus on the need to ask and answer questions in order to address the uncertainty across the span of a unit.

5.2.6. Instructional materials provide scaffolds for students as they develop expertise in framing questions and scoping problems across a lesson, a unit, and a year. Scaffolds address various aspects, such as developing good or productive questions where the answer isn't yet known or there are multiple answers, as well as the different types of questions (for example, sentence starters, criteria for evaluating questions, use of the driving question board throughout a unit, gallery walk to provide feedback on questions, think-pair-share, or comprehension checklists).

5.3 Opportunities for productive questioning are provided at key instructional junctions within a lesson or across a unit for all students.

Students are provided opportunities for productive questioning at key instructional junctions within a lesson or across a unit. Instructional materials include multiple opportunities that lead to productive questioning for all students, regardless if it is a science or engineering unit. Both teachers and students understand the importance of asking questions, and how asking questions at key points in learning enable them to understand the phenomenon studied. Especially early on in the scientific or engineering process, teachers may need to expertly draw attention to key conceptual gaps or puzzles in existing models or explanations to focus students' questioning. As the process continues, students become aware of these gaps by themselves. Teacher materials support this form of instructional expertise.

5.3.1. Units are designed to include key transition points or moments that problematize students' current understanding, in order to motivate additional, or the refinement of, questions to lead to new investigations about the phenomenon or problem.

5.3.2. Instructional materials provide opportunities for students to collect evidence from investigations that helps take steps towards resolving the problem or discrepancy in ideas and answering their questions.

5.3.3. Activities are included that focus on the link between the practice of asking questions to the other science and engineering practices, such as planning and carrying out investigations.

5.3.4. Teacher materials identify what needs to be *problematized* in order to motivate the learning across the entire unit, and provide sample phenomena that could motivate an important next step by raising new problems or discrepancies that allow students to ask a variety of productive questions (for example, flashlight on paper versus mirror, walking through a mirror-house hallway versus a regular hallway, or shiny metal jewelry versus paper-art jewelry).

5.3.5. Teachers are supported with strategies to capture and organize students' questions, and leverage these questions in future sense-making activities (such as a driving question board, flowcharts, tables, or concept maps).

5.3.6. Instructional materials provide multiple opportunities for both collective and individual record keeping of what questions all students have and what they want to figure out next, explicitly connected to what has gone on before. They provide scaffolds for students to make connections between models, phenomena, and questions explicit.

6–Planning and Carrying out Investigations

Planning and carrying out investigations is often the most salient feature of scientific work, in part because past images of science guiding instruction have focused on a 5-step "scientific method." However, this version of science is limiting in that it presents an overly simplistic version of science whose implementation is often the rote following of a set protocol.

The *Next Generation Science Standards* promote a version of scientific investigation this is part of a complex constellation of knowledge-building practices. What counts as an "investigation" is broader than the empirical control-of-variables investigations that have often been presented and focused upon in school science instruction. A core criterion of an investigation is that the proposed activity needs to generate evidence and that students must engage with the data as evidence. Equally important, a hands-on activity without talk or discussion around planning it, carrying it out, and interpreting and communicating what happened, is not considered an investigation, even if evidence is generated.

6.1 Instructional materials highlight connections between the practice of planning and carrying out investigations to the other practices and crosscutting concepts.

Students are supported to apply ideas present in the practice of planning and carrying out investigations in ways that explicitly and seamlessly link to other practices and crosscutting concepts. Planning and carrying out investigations is viewed as an organizing structure (hub) for the other science and engineering practices. Instructional materials emphasize connections between the practices and crosscutting concepts in order to leverage the role investigations have in developing deeper understanding of the disciplinary core ideas.

6.1.1. Students connect investigations to other practices and make explicit the connections between planning and carrying out investigations and other practices. For example, students need to plan and carry out investigations in order to test their current model, and they need to analyze and interpret their data from their investigation in order develop new models and questions.

6.1.2. The instructional design emphasizes the iterative nature of investigations and connections to other practices, and unit provide opportunities for students to engage in a series of investigations in which an answer to the initial question sparks the next question, which requires further investigation.

6.1.3. Instructional materials connect investigations to the crosscutting concepts, provide opportunities for students to design investigations, and focus on the connections between designing investigations and the crosscutting concepts (such as patterns, cause and effect, and scale, proportion, and quantity).

6.2 Investigations honor student agency to support student engagement and learning of disciplinary core ideas, practices, and crosscutting concepts.

Instructional materials provide opportunities around specific investigations to accommodate students' developing and evolving epistemic agency so that students' questions can be addressed in meaningful ways. Initially, developing questions to investigate is challenging for students and requires practice so that students can identify and ask questions that can be investigated and answered through the collection and analysis of empirical data. These investigations need to be authentic, relevant, and have a purpose from a student perspective that can be related back to the original student question and build to the next question.

Teacher materials guide teachers in how to allow students the space to plan and carry out meaningful, theory-based, valid, and reliable investigations while avoiding taking over the responsibility for the process, making the decisions about the process, or ending up scripting the experimental process.

6.2.1. Instructional materials promote meaningful investigations for students by providing opportunities to pursue investigations that stem from their own questions.

6.2.2. Units include multiple investigations so that students practice the planning and carrying out investigations and develop agency in the process. Planning and carrying out investigations is part of every unit with increasing levels of sophistication across the year, so that by the end of 8th grade students are implementing the complete practice as described in NGSS Appendix F. These investigations could be the same (or similar) investigations, or a series of investigations, that build to a deeper understanding of the underlying science.

6.2.3. Lessons and activities provide multiple opportunities for public documentation of all aspects of an investigation by students, including opportunities for students to identify and make public questions for investigation around a phenomenon, mechanistic models of a phenomenon, or an engineering design solution so they might revise, refine, or propose new questions for investigation.

6.2.4. Instructional materials embrace uncertainty and provide space for investigations that allow for students not knowing an answer or for being uncertain about next steps. They emphasize the importance of learning through productive hurdles and failures, embrace the challenges and uncertainty inherent in scientific investigations, and provide opportunities for students to make decisions and learn from them.

6.2.5. Explicit instructional supports allow for the development of student agency and ownership of learning across the unit using metacognitive strategies (for example, checklists, organizational tools, flow charts, driving question board, or model tracker).

6.3 Investigations have an authentic and explicit purpose for student sense-making.

Instructional materials support students in designing and carrying out investigations that allow students to develop a deeper understanding of the science being investigated. Scaffolds and support for students are provided to help them become skilled at applying ideas present in the planning and carrying out investigations practice in ways that link explicitly and seamlessly to other practices and to their own lived experiences, and that facilitate sense-making.

6.3.1. Investigations are part of a coherent constellation of activity and often have multiple roles (such as learning a scientific concept, developing experimental skills, gaining an understanding of how scientific knowledge is produced). Instructional materials emphasize that the nature of investigations will vary based on the question being asked and the discipline being studied.

6.3.2. Instructional materials focus on investigation authenticity and include investigations that are connected to students' past experiences in and out of the classroom that are developed out of students' own questions.

6.3.3. Classroom science is explicitly linked to the scientific enterprise. Lessons make explicit the relation between the investigations students are doing in class and the scientific endeavor, allowing for explicit connections to the nature of science.

6.3.4. Students apply investigated ideas to real world. Instructional materials create opportunities for students to apply the investigations they are doing in class to their own lived experiences or meaningful contexts.

6.4 Teachers are guided in creating a supportive space for student-centered investigations.

Instructional materials support both students and teachers in learning how to navigate learning with student-centered investigations. Central to this design specification is the idea that a "hands-on activity" without talk or discussion around planning it, carrying it out, and interpreting and communicating what happened, is not an investigation.

Planning an authentic investigation involves making a series of decisions that require experience and expertise. These decisions involve identifying and revising questions with a specific purpose in mind as well as understanding how to structure and carry out valid, reliable empirical investigations. Students often struggle with understanding that experiments are based on theory, and that they need to be planned and grounded in selecting specific variables to test, and they must have a reason to conduct the experiment. Students need both teacher and peer support as they engage in science learning by participating in the practices of science, constructing their own understanding of what it means to be a scientist or engineer, and to do and learn from science.

6.4.1. Lessons and activities provide pedagogical scaffolds and supports for helping students plan and conduct empirically based, valid, and reliable investigations (for example, providing supports and rationale for iterating on a single investigation or a series of investigations).

6.4.2. Instructional materials emphasize the importance of discussions, and provide support and space for students to *talk* (not just *do* hands-on activities) while engaging in the planning and carrying out investigations practice. They support rich class discussions for procedural and practical purposes, and engage students in discourse to uncover the necessity for gathering observations or data (students are supported in figuring out *"what do we need to know?"*) as well as to engage students in defining the strategies or methods used for collecting observations or data (*"how will we come to get the information we need?"*).

6.4.3. Instructional materials support rich class discussions for sense-making, and emphasize the centrality of discourse for sense-making throughout the planning of and carrying out of an investigation (not just at the start and end of the investigation). They emphasize the importance of learning through productive hurdles and failures, embrace the challenges and uncertainty inherent in scientific investigations, and provide opportunities for students to make decisions and learn from them.

7–Developing and Using Models, Constructing Explanations, and Designing Solutions

Developing and using models is an intellectual endeavor that guides scientific work and goes well beyond simply drawing pictures. It can be challenging to create the conditions in the classroom that engage students in a deeper version of this practice that goes beyond depiction. OpenSciEd instructional materials position models as intellectual tools that students use to reason with and use to develop explanations for phenomena. This intellectual work happens through negotiation between students, whether in small groups or in a whole group setting, and important learning happens in the discussions students have while deciding how to construct or revise models and how to explain a phenomenon or design a solution. For further guidance on implementing these design specifications, refer to NGSS Appendix F.

7.1 Developing models and constructing explanations are central to the units.
The practices of "Developing and using models" and "Constructing explanations and designing solutions" are central to science and the way that scientists make sense of the world. The creation of models and explanations is both the goal of an OpenSciEd classroom and the means by which learning occurs. Through these practices, students achieve and demonstrate key understanding of the disciplinary core ideas and crosscutting concepts. Modeling and explanations are also central in that they coordinate and guide the use of the other practices.

7.1.1. The development and revision of models and explanations is the central activity of all instructional materials. Each unit has one or more models (or model revisions) that serve as organizing features for the unit. Some repeated routines are established within units and within grades so students can practice and improve upon development and revision of models, and approximately 25% of homework and other activities focus on the cycle of model development, explanation, and revision.

7.1.2. Science and engineering practices are coordinated and support one another. Instructional materials connect modeling and constructing explanations and solutions to the other scientific practices going on in the classroom so that they are informed by and inform questioning, investigations, data analysis, math and computational reasoning, argumentation, and communication.

7.1.3. The target disciplinary core ideas and crosscutting concepts of each unit are closely aligned with the development of models, explanations, and solutions. Engaging in these practices is always in service of developing understanding of important disciplinary core ideas and crosscutting concepts. Developing models, explanations, and design solutions are not additional activities but rather are positioned as central to the unfolding sense-making work of the classroom.

7.2 Supports and scaffolds manage the complex practices of modeling and explanation.

Developing models, explanations, and solutions is complex and cognitively demanding. This process needs to be carefully scaffolded so that students and teachers have the support they require for managing the complexity and demand, while responsibility for the models and explanations remains with the classroom community. It can be challenging to move beyond depiction and drawings in the modeling practice, or position models as more than a container for declarative knowledge (a glorified worksheet) to be memorized. Explanations need to go beyond unstructured storytelling. They need to provide clear answers, based on evidence and established model ideas, to *how* and *why* questions about phenomena.

7.2.1. The practice of developing and using models always has the purpose of constructing an explanation for a phenomenon or providing the basis for a design solution. An activity to focus the classroom knowledge building work on a specific phenomenon or class of phenomena occurs in the first lesson set of each unit and in other lessons where new phenomena are introduced to drive the model building. For example, students are asked to develop a model to explain how the plants on the windowsill grew, or what happened to the puddle on the playground, rather than being asked to draw a model of cell division or evaporation. Usually the purpose is communicated with a clear question that the model can be used to answer in the form of an explanation or a design solution. These questions focus on causal mechanisms to move from simple *what* explanations to *why* or *how* explanations. Instructional materials require students to develop explanations using their models, which often requires pressing for an unseen cause of the phenomenon (for example, molecular motion or differential survival).

7.2.2. Instructional materials draw a clear distinction between developing a model and representing it. They avoid the phrase *"draw a model"* and instead use language such as *"develop a model and represent it"* that puts the cognitive demand on the students. For example, instructional materials will ask *"What do you think needs to be revised in your model?"* as opposed to *"Today we learned about evaporation. Please be sure it is represented in your model."* The learning occurs as students negotiate what does and does not get included in their models.

7.2.3. Students are provided with explicit opportunities to share their ideas with one another and evaluate them based on established criteria. Instructional materials include repeated and explicit conversations about how to evaluate knowledge products in the classroom, and how they connect to other practices. These criteria are established in each classroom at the beginning of the year and revisited in each unit.

7.2.4. Students represent models in multiple ways that convey different aspects of underlying model ideas. Instructional materials require that models about the same ideas be represented in multiple ways to convey underlying model ideas. Typically this is a combination of labeled drawings and text statements. Some models cannot be easily represented in pictorial form (such as natural selection) and in those cases it is okay for a model to exist as a list of principles in text only. Models are not represented with drawings or pictures alone. When using simulations, instructional materials ask students to connect the computer output to the underlying rules or code that runs the simulation.

7.3 Modeling and explanation involve an iterative process of revision.

To provide an authentic experience of making sense of phenomena through modeling and explanation, students have multiple opportunities to return to their ideas to revise, discard, add or expand them as they gain new evidence from investigations and other sources (readings, simulations, further observations). Students use their models to develop explanations and in so doing realize where there are gaps or issues that need to be taken up to move forward.

7.3.1. Students develop and revise models and explanations over time based on new information gained through investigations and discussions. Instructional materials include multiple opportunities to create models, construct explanations, and design solutions, and return to them to revise them based on their ongoing work. The instructional materials have clear stopping points for this revision to happen and include opportunities for students to develop and share initial ideas about the anchoring phenomena, identify gaps in their understanding, revise their ideas each time they have new information (from investigations, readings, simulations), and return to their models in explicit ways at the end of the unit as they come to closure in explaining the driving questions.

7.3.2. Students have opportunities to apply their models to explain multiple phenomena. Model and explanation development is centered on an anchoring phenomenon. At least once in all units there is an explicit conversation or activity that requires students to consider how their model could be modified to account for a different related phenomenon or be generalized to account for a class of phenomena.

7.3.3. Instructional materials provide explicit opportunities for the students to map between their model and explanations or design solutions. Students use their models when constructing explanations or identify gaps in their explanations that imply a need for new ideas in the model. Going back and forth between explanations and solutions and models is an important feature of these practices. The model points to the unseen, underlying mechanisms at play and the explanations and solutions connect those unseen and often abstract ideas to the specifics of the phenomenon or design challenge. Instructional materials are explicit about these connections toward the middle and end of a unit, and might include a prompt that asks students to write an explanation or develop a solution and then go back to their model and annotate where each part of the model shows up in their explanation or design solution.

7.3.4. Instructional materials require students to use their models for a purpose. Models are dynamic and need to be applied to be useful. When assessing understanding of the models under development, students are asked to use the model, not to just describe it. Most often this involves students using their model to develop an explanation. Students are not asked to simply repeat back an element of a model or even an entire model as an inert fact.

7.4 Students experience modeling and explanation as collaborative processes.

In scientific communities, modeling and explanation are collaborative endeavors that advance the understanding of the members of the community. Instructional materials are structured so that the that work of the classroom community is made public, and students have opportunities to share, critique, and build on one another's ideas throughout each unit.

7.4.1. Activities are structured so that students work together through a collaborative process to develop and revise shared models that represent a class consensus. Instructional materials provide scaffolds and routines that support collaboration and class consensus about models, explanations, gaps that need filling, potential investigations, and revisions to the models.

7.4.2. Teacher materials guide teachers in keeping public records of the ongoing models that the students are creating (either digitally or through posting on a wall or board) and provide guidance on the format of those artifacts and how to hold students accountable for keeping their own individual records.

8–Analyzing and Interpreting Data and Using Mathematical and Computational Thinking

Instructional materials provide students with opportunities to learn the practices of "Analyzing and interpreting data" and "Using mathematics and computational thinking," with ample opportunities for students to use these practices to develop explanations and design solutions. Often when exploring a natural event or thinking about solutions to a problem, we are not just interested in describing *what* is happening. We are also interested in *how much*, *how fast*, or *how frequently* something has happened, and how it may happen in the future or in a different circumstance. Both of these practices offer specialized ways for describing the observations made during investigations precisely and systematically. Analyzing and interpreting data is about developing, exploring, and conducting analyses on observations that have been precisely recorded and are meant to reflect aspects of the natural world. Using mathematics is about describing a system of interest quantitatively, and computational thinking focuses on using a computer to simulate the processes and relationships that make up a system, or using digital tools to analyze and visualize large datasets or mathematical relationships.

"Analyzing and interpreting data" and "Using mathematics and computational thinking" are best understood relative to the other practices. "Asking questions and defining problems" *enable* them, "Developing and using models" and "Planning and carrying out investigations" are *interwoven* with them, and "Constructing explanations and designing solutions," "Engaging in argument from evidence," and "Obtaining, evaluation, and communicating results" are *enabled by* them. These practices involve making use of statistics, mathematics, and computation as specialized tools for organizing and analyzing the products of investigations in order to build scientific models, develop explanations, and design solutions.

8.1 Instructional materials focus on students' ability to contextualize data, mathematical models, and simulations.

Data, mathematical models, and simulations are human-constructed abstractions of the world. Data are conceptualized as collections of numerical values (lengths, number of clicks, voltages, temperatures) or qualitative representations (field notes, sketches, photo, video, or audio records) collected from systematic observations of the natural world, investigations such as experiments, or generated through automated means such as simulations or environmental sensors. Mathematical models describe the important quantitative patterns and relationships embedded in natural systems, and simulations are computer models that encode some of the behaviors or relationships that unfold in scientific systems over time. A perpetual challenge for students is to connect these abstractions back to the world from which they originated.

Students already know a tremendous amount about the natural world that is used as a resource for thinking about how data, mathematical models, and simulations are created. At the same time, the conventions used to create these abstractions (for example, the processes of obtaining and recording data, describing quantitative relationships algebraically, or translating behaviors in the world into computer algorithms) are tacit and are supported through well-facilitated instruction. Supports build on students' prior understandings, but also help them to see the rationale that underlies existing conventions. The goal is to help students recognize that data, mathematical models, and simulations are human-constructed abstractions grounded in observations of the natural world.

8.1.1. In units that involve collecting and working with data, students reflect explicitly on measurement. When collecting data themselves, students are given opportunities to choose between multiple measurement options, or to develop their own. When provided with data, students are asked to consider how measurements were taken and discuss possible alternatives. Students are asked to assess possible sources of error or imprecision in data due to measurement choices. In at least one unit per year, students have the opportunity to collect data using a variety of measurement methods they select themselves, compare the results of their findings, and then iterate on their data collection methods.

8.1.2. In units that involve working with data, mathematical models, or simulations, students are asked to describe connections between what is visualized or represented and their real-world referents. Instructional materials include opportunities for students to consider what important features of the phenomenon under investigation might be missing from the dataset, mathematical model, or simulation.

8.1.3. At least half of these units provide opportunities for students to observe and reason about *more than one* outcome (for example, what different patterns or trends in data, results from mathematical models, or output of simulations imply for the same natural phenomenon under investigation), which is especially appropriate for engaging students in the testing and comparison of proposed solutions to engineering design problems.

8.1.4. At least half of these units provide students with opportunities to create their own mappings between abstractions and natural phenomena (for example, students may be asked to label axes, name columns or collections of data, or develop their own variable names for mathematical models or simulations).

8.1.5. To avoid treating data analysis, mathematical models, or simulations as *input-output* processes that simply generate results rather than as models of the world, instructional materials focus on grounding both the inputs and outputs of these sources of data. Units that involve data, mathematical models, or simulations include opportunities for students to explore mappings between abstracted *input* parameters (individual data points, input variables, simulation setup conditions) and the natural phenomenon of interest. At least half of such units provide students with opportunities to make predictions about what real-world outcomes will result based a given set of inputs *before* an output is calculated, or given a particular output, to determine what real-world conditions may have led to that output.

8.1.6. Students have at least three opportunities over the course of a year to record their own observations of natural phenomena, with the goal of encoding those observations as data, mathematical models, or simulations. For example, students may be asked to develop their own data tables for a planned investigation, to hypothesize the rate of growth (additive, multiplicative, exponential) of a biological organism, or to observe a physical system (ants, moon cycle, projectile motion) with the ultimate goal of describing its behavior in terms of algorithmic rules.

8.2 Students develop their statistical, mathematical, and computational toolkits.

Once students have assembled or been provided with a dataset or simulation and understand its connection to the natural world, they can begin to make use of statistical, mathematical, and computational tools to explore the patterns within. The practices of "Analyzing and interpreting data" and "Using mathematics and computational thinking" both involve selecting and making use of a wide variety of technological, conceptual, and representational tools. Some are broadly useful, such as the concepts of variability and distribution, representations such as histograms, line graphs, and algebraic equations, or tools such as spreadsheets. Others, such as maps, agent-based simulations, or box-and-whisker plots are more specialized and may only be appropriate in certain circumstances. Understanding and navigating this landscape of available tools is critical for engaging in the practices of data analysis and mathematical and computational thinking.

A challenge for students is to recognize that on one hand, there is no "one right way" to analyze or model natural phenomena (in fact, sometimes using multiple tools together provides more insight into a dataset or system). On the other hand, certain tools are more appropriate to use depending on the investigation you are conducting or problem you are solving, and some tools may be inappropriate or lead to invalid conclusions. One powerful way to address this challenge is to leverage the diversity of approaches that students are likely to bring to any classroom investigation. Different student approaches to the same investigation might be more or less useful in moving students' investigations forward, and different tools might be useful in different ways. This approach avoids the implication that there is one right way to conduct analysis or modeling, but it does teach that some approaches can be inappropriate for a particular task. Through repeated experiences making use of these tools, especially to address well-grounded problems whose connections to natural phenomena are known, students can begin to appreciate when and why certain tools work for some investigational contexts, but not others.

8.2.1. Students are given many opportunities—especially toward the beginning of the academic year—to choose, apply, share and compare among a variety of statistical, graphical, and digital tools while working on a shared problem or investigation.

a. As part of these opportunities students review and critique their peers' solutions, are asked to consider how different approaches might reveal or obscure important features of the phenomenon under study, and are given the opportunity to modify their own approaches.

b. At least one opportunity each year focuses on selecting from a variety of *statistical measures* (mean, median, mode, variability) or to develop their own statistical measures when describing basic distributions of quantitative data (for example, to draw conclusions about some measure for which two populations differ in mean and variability, one with a higher mean but lower variability versus one with a lower mean and higher variability, or asking students to describe or predict the "most typical" of a population with considerable variability).

c. At least one opportunity focuses on selecting from a variety of *graphical displays* (maps, charts, graphs, tables) or displays that students invent themselves to analyze data. At least one opportunity focuses on selecting from a variety of *digital tools* when analyzing data (spreadsheets, data visualization tools such as Tuva, Fathom, or CODAP), working with mathematical models (graphing tools such as Desmos or Geogebra), or creating or interacting with simulations (Scratch, NetLogo, Sage Modeler).

8.2.2. Students are asked to explore the nature and causes of variability in data, and to discuss whether it exists naturally or because of measurement error. Variation from both error and natural variation is acknowledged in every unit involving datasets collected from the natural world. Students have at least one opportunity to engage with, and work to differentiate between, error and natural variation in data. Students have an opportunity to observe or discuss the degree to which natural variability is accounted for (or more often, not accounted for) in mathematical models and simulations of scientific phenomena.

8.2.3. Whenever they analyze data collected from the natural world or produced by simulations, students are asked to consider questions of causation, correlation, and significance.

a. In any unit that requires students to make conclusions based on differences between measures in collected, provided, or simulated data, students' intuitions about statistical significance (as reflected in differences between measures or trends) are elicited and reconciled with their intuitions about practical significance (dependent on the situation and circumstances).
b. In any unit that requires students to make conclusions based on relationships or trends identified in data, differences between causation and correlation are raised and considered. Students are asked to share their concerns about whether the nature of data collection (controlled experiment or observational sampling), the mechanisms that underlie the phenomenon of interest (known or suspected causal variable versus possible confound), and how alternative hypotheses for observed relationships limits their ability to make causal inferences.

8.2.4. Students are asked to make connections between data, mathematical models, and simulations as different but related ways to model scientific phenomena. Students compare each pair of abstraction type (data analysis and mathematical models; data analysis and simulations; simulations and mathematical models) and discuss differences in treatment of causation, variability, measurement, and what is modeled. If possible, connections should be made between student-constructed abstractions as well as student-constructed and curriculum-provided abstractions.

8.3 Data, mathematics, and computing are specialized forms of modeling.

The prior issues focus on emphasizing the human-constructed and interpretive nature of work with data, mathematical models, and simulations. Because of their complex and technical nature, students might continue to see these abstractions as illustrations of factual truth, rather than models constructed by humans to highlight particular aspects of a scientific phenomenon. Alternatively, they may view them merely as communicative artifacts meant to *show* their own knowledge of scientific facts, rather than also as a way to *figure out* the world.

To address this challenge, instructional materials position all datasets, mathematical models, and simulations—regardless of whether they are provided as a part of instructional materials, sourced by students during investigations, or created by students—as *scientific resources and models* whose validity is established through their connections to natural phenomena, explanatory and predictive power, and utility toward particular student-defined goals. Students construct and make use of more sophisticated mathematical or computational models to explore, explain, and predict complex causal chains or multi-level relationships in systems.

8.3.1. As appropriate, and at least three times within the academic year, data visualizations, mathematical expressions or equations, and simulations are put forth as options for students to use to represent models. Mathematical expressions or equations are appropriate for encouraging students to clearly articulate and elaborate models that predict certain quantitative relationships. They are a useful way to plan and prepare for controlled experiments. Simulations are an appropriate way for students to express and test their models of enacted behaviors in a wide variety of scientific systems (physical, chemical, or ecological). Introducing data, and encouraging students to develop data models, is an effective way to provoke critique and revision of their earlier models.

8.3.2. When multiple examples are available, students are invited to compare data, mathematical models, or simulations pertaining to the phenomenon under study to explore what each emphasizes or downplays.

8.3.3. Data, mathematical models, or simulations are never used as a direct "check" of student work or theories. Instead, they should be presented as an additional resource, evaluated in terms of its explanatory and predictive power, clarity, and other criteria for validity that have been established by the classroom community.

8.3.4. In any unit that makes use of curriculum-provided datasets, mathematical models, or simulations, students are asked to consider their “life cycle.” Specifically, students learn about and question who authored the datasets, models, or simulations, what their goals were, what they chose to select and leave out, what are the possible limitations and threats to validity imposed by this resource given students’ own interests and paths of investigation, and whether students would have made different decisions if they were the authors instead.

8.4 Instructional materials sustain data analysis, mathematics, and computational thinking as classroom practices.

For students to develop more complex understandings of interpreting and analyzing data and using computational thinking over time, instructional materials must shift from a focus on learning concepts to a focus on co-developing concepts alongside these practices. Practices are a form of hidden instruction, and inviting students to contribute to the development of practices can help them understand their overarching purpose, when and why they are useful for developing knowledge, and how to participate in and transform those practices in service of their own personal, in-the-moment goals. For students, the move to practices means learning new things (practices as well as concepts), doing so in new ways (invention, critique, and revisiting), and playing a central role in determining what counts as good work (students, rather than teachers, evaluating their own work and the work of others).

For teachers, the move to practices means engineering student encounters with problems of practice; orchestrating cycles of construction, critique, and revisiting; and supporting the interplay of individual and collective histories of development. Instructional materials encourage students to connect their use of data, mathematics, and computing across different problems and experiences. The idea that practices make use of a broad, flexible kit of mathematical and computational tools rather than “how to scripts” are reinforced by revisiting, maintaining flexibility, and building connections across the tools and approaches students use during various investigations over time.

8.4.1. Teacher materials characterize the intended development of data, mathematical, and computational concepts and practices in construct maps or learning progressions. These maps provide teachers with interpretive systems they can use to evaluate a range of student products, describe a continuum between expected beginning and ending points in a given unit or grade to address the progressive nature of learning, and offer guides to help teachers understand the range of student responses expected during a given activity, and decide on next steps in instruction.

8.4.2. Instructional materials support the development of practices with sequenced experiences. A unit might begin with measurement and contextualization tasks, move to encoding, invention, and comparison tasks, offer new contexts in which preferred tools and approaches might be re-employed or expanded, provide ways to connect preferred tools and approaches to one another, and make use of recurring classroom activity structures (for example, familiar cycles of invention, critique, and revisiting practices in formative assessments with new content or tools).

8.4.3. Teacher materials make the logic of the instructional design transparent and actionable to teachers. They demonstrate how the problems of practice and classroom activity structures are designed to elicit a variety of ways of thinking that can be seen and understood, and offer suggestions for using the heterogeneity in student thinking to support the emergence of group concepts, forms of practice, and links to convention.

9–Arguing from Evidence and Obtaining, Evaluating, and Communicating Information

Students learn more when engaged in meaningful forms of argumentation and communication. Instructional materials provide structured opportunities for students to participate in arguing and communicating about elements of their work for the authentic purpose of explaining a phenomenon or designing a solution, at increasing levels of sophistication over time.

9.1 Argumentation and communication vary across individuals, classrooms, disciplines, and out-of-school contexts.

Enabling every student to be successful requires creating opportunities for students' home experiences, and ways of knowing, to be a productive part of the classroom sense-making. Instructional materials support this is by showing the ways argumentation and communication vary across individuals, classrooms, disciplines, and out-of-school contexts. They include vignettes, sample student work, interviews conducted with scientists and engineers about their argumentation and communication, and comparisons of the language used to describe these practices. For further guidance, refer to NGSS Appendix F.

9.1.1. Teacher materials include educative examples for teachers to help them understand the productivity inherent within student variation of ideas and practices (for example, synthesized vignettes of classroom activities, sample student work, or transcripts or videos of classroom activities).

   a. Examples show variation in how individuals participate (participation does not always require verbal participation in whole class discussions) and ways that students argue and communicate successfully (emphasizing differences that stem from students' backgrounds and experiences, familiarity with the practices, comfort with English).
   b. Teacher materials provide examples of how teachers explicitly use and build on students' ideas, including incorrect ideas that do not initially appear productive. They show how teachers explicitly make connections among student resources, what students are doing in science classrooms, and the

intended disciplinary practices associated with argumentation and communication.

c. Examples show variation in the sophistication of the students' scientific reasoning and articulation of their thinking, and in school contexts and student demographics (gender, race, language proficiency) to highlight the ways that all students are capable of engaging in argumentation, and obtaining, evaluating, and communicating information.

d. Examples of students engaged in arguing and communicating in the sciences and engineering enable teachers to help students "see" how communicating and arguing are interrelated but different. Examples show variation with respect to when in the investigation students are arguing and communicating so that it's clear that these practices aren't only part of a culminating task.

9.1.2. Educative examples show teachers the ways in which the variation shown in the examples is consistent (or inconsistent) with disciplinary practices (for example, how scientists and engineers argue and communicate and why).

9.1.3. Examples show how to emphasize the productivity of what students are doing, and help teachers think about ways they can recognize and build on student resources for engaging in argumentation and communication, including multimedia examples and vignettes (such as real classroom videos and audio clips).

9.2 Students engage in argumentation and communication to explain phenomena or design solutions to problems.

When students are engaged in meaningful forms of argumentation and communication—when they have an authentic reason to argue or to communicate—their performance is better. Instructional materials ensure that students are arguing and communicating about elements of their investigative or design-related work (involving the other practices), for the authentic purpose of explaining a phenomenon (or elements of it), or designing a solution.

9.2.1. Instructional materials create contexts in which students are explicitly focused on figuring something out, and on the criteria they use to evaluate their ideas and processes, rather than focusing solely on demonstrating acquisition of a "right" answer.

a. The goal of argumentation and communication is sense-making—"figuring it out"—and the right answer is learned by using particular scientific or design criteria as they attend to that goal. The right answer is a tool to achieve the goal, rather than being a goal in and of itself. Instructional materials make these criteria part of the assessment and discussions.
b. With respect to engineering, the criteria are project "constraints and criteria" which become the primary means of evaluation (and can offer the potential for multiple "right" answers, as long as the design requirements are achieved).
c. With respect to argumentation and communication, teachers and students are asked to explicitly build on evidence, past experiences, or shared ideas to address the question asked, construct ideas with appropriate levels of generality, and address the needs of their audience.
d. Lessons ask students to self-assess their own arguments, designs, and communicative practices and products, in addition to assessing those of others. For example, *what worked well in my design? What parts of my argument were well supported? What parts might require more evidence or better explanation? Given my audience, did the communicative genre I chose help them understand my ideas?*

9.2.2. Lessons and activities make students' work with argumentation and communication public because argumentation and communication are inherently public practices (whether written, spoken, or illustrated). Making an argument public, for example, is essential for others to respond and evaluate the thinking and reasoning behind it. This means both sharing final form ideas and showing, discussing, and debating "works in progress," including justifications for students' decisions.

9.2.3. Units provide students with opportunities to engage in purposeful revision of their argument and communication-related processes and products. For example, students revise their solution if they receive feedback that it does not address elements of users' needs; students revise their claim if they receive feedback that it does not align with the investigative question or if it does not attend to the evidence generated; and students re-examine their decision-making processes if they select a genre that is not aligned with the intended audience and purpose (such as writing the discussion section of a scientific poster as a story rather than an argument when writing for a scientific audience).

9.2.4. The practice of argumentation happens where uncertainty is expected and enabled, either as a result of disagreement or because they are in the midst of sense-making.

a. Argumentation can also occur around questions that feel resolved to students. Students must have a meaningful reason for engaging in argumentation in these situations. For example, they might be providing an argument others could use, or articulating their final form argument in a way that could convince others.
b. Argumentation occurs throughout science investigations, not only as a culmination of students' work. Students may argue about the appropriateness of their questions, research methods, or data interpretations, just like scientists do.
c. Argumentation occurs throughout an engineering design project, not only as a culmination of students' work. Students may argue about their interpretations of the user's needs, about which materials, resources, and methods they think will work best in the design, about how well a design fits the criteria, and about the relative prioritization of different potentially competing design criteria as well as other considerations such as feasibility of construction and optimization.
d. Argumentation does not always require consensus. Teacher materials help teachers identify when consensus is necessary and when it is not. Argumentation occurs in speaking (talk stems, teacher and peer modeling) as

well as writing (sentence stems, graphic organizers, and opportunity for revision).

9.2.5. In instructional materials, students obtain, evaluate and communicate information throughout an investigation or design project, not only as a culmination of students' work. For example, students obtain and evaluate background information that helps situate their investigative work, or they might conduct user needs assessment.

a. Students communicate their preliminary investigative findings, or the affordances and constraints of their designs, to other peer groups, in addition to communicating findings, understandings, explanations, or design solutions, to teachers, community groups, or family members. Students consider audience, purpose, and genre when engaging in science and engineering-related communication, and they experience many opportunities to communicate to different audiences, for different purposes, using a variety of genres, in speaking as well as writing.
b. Students use information from a variety of sources (books, journals, online blogs, videos, photographs, interviews with community members) and decide what information and sources are most relevant to their tasks as part of their investigative work. In some instances, students learn how to search for these sources (conduct keyword searches in online databases, learn to use their libraries' systems for finding sources and information, learning how to conduct information-gathering interviews with family and community members), while in other instances activities include texts in varied formats and genres that provide evidence and other information needed for sense-making.
c. Instructional materials include excerpts or adapted versions of important science formats, including the opportunity for students to make sense of diagrams, tables, graphs, and procedural instructions. Texts do not provide an explanatory account of the phenomenon, but rather are a source of evidence, a component piece of information that can contribute to figuring out the phenomenon, or additional examples and counterexamples to allow

students to support claims or reject claims, or to generalize claims or narrow claims as needed

d. In order to develop both receptive (reading and listening) and productive (speaking and writing) communication skills throughout the investigative and design processes, supports are provided for listening in addition to reading, such as the setting of norms and expectations for active listening, teacher talk that sets the expectation for listening to and working with the ideas of peers, talk stems, and teacher or peer modeling.

9.2.6. Engineering design projects use disciplinary core ideas in authentic and purposeful ways such that those ideas are clearly necessary for achieving the design goals. Instructional materials might also expose students to real examples of how scientists and engineers use the practices of arguing and communicating as part of their work. Students explore why and how this is essential to the field and to building knowledge and a collective understanding about our world. Instructional materials embed some vignettes or real-world examples of a way someone's engagement in argumentation and communication has helped respond to a question or propose solutions to a problem related to the core ideas being explored in that unit.

9.3 Students participate in argumentation and communication at increasing levels of sophistication and decreasing levels of scaffolding over time.

Instructional materials support students in participating in argumentation and communication practices in increasingly sophisticated ways as they become increasingly familiar with these practices. Sophistication includes the structure, content, and interactions within the students' communication and argumentation, as well as the context (scaffolding and activity structures).

9.3.1. Instructional materials use the *Common Core State Standards for English Language Arts* to support and scaffold grade-appropriate uses of the literacy skills in their transfer to grade-appropriate science practices. They acknowledge where scaffolding needs to be provided in order to support a more sophisticated use of literacy skills in the disciplinary context, particularly in Grades 3-5, and to gauge reasonable boundaries and identify necessary scaffolding for the literacy skills needed to engage in scientific argumentation and communication in Grades 6-8 and beyond.

9.3.2. The *claim-evidence-reasoning* framework tis used to support students in argumentation, particularly in the earlier grades. The use of this framework fades over time, and teacher materials provide both general and specific prompts at different points in the unit. Instructional materials support students in distinguishing between argument and opinion by Grades 3-5, so that they begin to understand and have experience with the ways that opinion and argument differ, and that the reasons they give are grounded in evidence and logic. By Grades 6-8, instructional materials support students in distinguishing between fact and inference (or even speculation) and provide opportunities for students to develop clear understanding of what constitutes a claim and the types of evidence (data and observations gathered systematically) and reasoning (logical versus emotional) that are valued in science.

9.3.3. Students have multiple opportunities within a single unit and across the instructional materials to practice evaluating the credibility, validity, and reliability of the information they obtain, and to practice communicating information to a variety of audiences for different purposes (for example, a scientific audience for the purpose of sharing research, their families for the purpose of sharing what they are investigating in school, a local museum for the purpose of helping to construct an exhibit). Students practice selecting the genre of communication that best suits a given audience and purpose, and they have opportunities to move across multiple representations of the same ideas.

9.3.4. Lessons and activities provide students with a purpose for argumentation and communication. Students can do more when they are engaged in meaningful forms of the practices—when they have an authentic reason to argue or to communicate in various ways—thus scaffolds are imbued with a purpose that aligns with the expectations such that student work can be meaningful. Scaffolds do not oversimplify such that they obscure the sense-making purposes.

9.3.5. Instructional materials provide students with opportunities to identify and obtain information from a variety of sources and depending on purpose (for example, interviews, print text like journal and review articles and newspapers, videos, photographs, graphical representations). Students learn to search and use databases and various search engines to obtain information.

9.3.6. Teacher materials include educative supports that help teachers model their thought processes when evaluating whether information is accurate, credible, or useful.

9.3.7. Students are provided examples of how to evaluate information in light of the task at hand. For example, some data may be interesting and credible but useless given the task. Students start to use a scientific stance of "skepticism" to evaluate the information based on the quality of evidence and reasoning, or any potential bias that might come from the author's intended purpose and audience.

9.3.8. Instructional materials support students in creating arguments and communicating ideas that increase in content sophistication but also in the sophistication of the contexts in which the argumentation and communication is happening, recognizing that teacher led discussions are often a less sophisticated form of the argumentation and communication than student to student discussions because of the teacher’s dominate role.

9.4 Instructional materials support the linguistic demands of arguing and communicating.

To enable *every* student to successfully participate in scientific practices, instructional materials attend to the linguistic demands inherent to engaging in the particular practices of arguing and communicating across productive (writing and speaking) and receptive (reading and listening) language functions.

9.4.1. Instructional materials provide a variety of examples of language supports for teachers that can help their students with linguistic demands (relative to writing, speaking, reading, and listening).

a. For argumentative and communication-related writing and speaking, the instructional materials make use of supports like sentence starters and talk strategies. For argumentative and communication-related reading and listening, instructional materials make use of routines like identifying "survival words" (students identify important words that are necessary for understanding a text), "word detectives" (students analyze words to explore word meaning for comprehension), and "sentence detectives" (students practice sentence analysis techniques like exploring the concepts and ideas in individual sentences and then investigating the relationships among sentences).
b. Instructional materials make use of listening strategies, such as helping students learn to pay attention to words that are repeated often, and "stressed" words (that are spoken longer and louder) because these words are usually an indication of importance. With respect to supporting students in listening to each other, instructional materials emphasize the importance of talk strategies for listening carefully, using phrases such as, "I hear you saying that...," "If I understand you correctly, your claim is...," and "I think you are saying that your audience is..." Additionally, the materials provide supports for helping students learn how to productively summarize or add to what their peers are saying (for example, teachers are prompted to ask "Does anyone want to add onto that?" and "Can anyone summarize what they said?").
c. For argumentation-related writing, speaking, reading, and listening, instructional materials make use of supports like vocabulary instruction of argument-related words, peer modeling, and the modeling of language expectations for an activity.

9.4.2. Instructional materials encourage teachers to reflect upon how their students currently engage in the language requirements embedded in arguing and communicating, and reflect on their own instructional strategies for supporting students in this literacy work.

a. Teachers are guided in using strategies to better understand what students think “argumentation” is and how students go about arguing in various contexts in their lives. For example, teachers can ask students to pick some activities in which they engage outside of school and identify what they might argue about in those activities, what claims they might have to make, what types of evidence they use to support their claims, and how that is dependent on the activity itself (for example, in basketball there might be an argument about whether someone travelled, and video tape might be analyzed to find evidence to support that someone did travel). From there, teachers can compare the structures and processes involved in students’ everyday argumentation with the structures and processes involved in scientific argumentation and help students “code switch.”
b. Teachers are guided in using formative assessments to better understand what students know and are able to do with respect to obtaining, evaluating, and communicating information (Do students know how to use search engines and keyword searches to obtain information? Do they know how to assess the credibility of a source that they find? Do they know how to select an appropriate genre to communicate their explanations given the intended audience?).
c. Instructional materials support teachers and students in the use of techniques like functional grammar analysis to identify certain patterns in scientific texts (such as compare and contrast, problem and solution, or cause and effect).

9.4.3. Instructional materials use language supports like discourse markers to analyze existing arguments and to produce them. They support teachers in helping students learn to identify discourse markers in scientific text and talk, and use them in their writing and speaking. For example, markers can include words and phrases such as *“because,” “we contend,” “therefore,”* and *“others might argue.”*

9.4.4. Teachers are guided in using these different language supports at various points throughout the materials, ideally when students are about to engage in a particularly demanding task. Teacher materials include suggested language supports when appropriate, including when a task is introduced for the first time (for example, the first time students read their peers' written arguments to give them feedback related to strength and persuasiveness). However, a language support is not included for every lesson. The goal is for teachers to build a repertoire of practices that they could incorporate to better support their particular students.

9.4.5. Instructional materials embed metacognitive prompts to support teachers with having metacognitive conversations around the disciplinary literacy goals associated with argumentation and communication.

a. For argumentation, teachers and students are prompted to ask the following types of questions: *What is the claim being advanced? What is the evidence for this claim? Is the evidence convincing? Is all of the evidence being considered? Are all of the plausible claims being addressed? Is the reasoning logical and valid? Why or why not?*
b. For obtaining, evaluating, and communicating information, teachers and students are prompted to ask the following types of questions: *Given the phenomenon we are exploring, what types of information do we need to obtain to better understand that phenomenon? Where should we look for that information? How will we know if the information we find is credible and accurate? What are the important ideas that need to be included in the explanation? What would be the best way to organize the ideas? How did we decide the best way to organize the ideas? What is the purpose for this communication and who is the intended audience? What format would best be used to communicate with this audience for this purpose? Is my choice of language suited to the audience?*

10–Crosscutting Concepts

Crosscutting concepts are central to robust and applicable science understanding. Crosscutting concepts are not mere concepts, facts, or definitions for students to learn, rather, they are *ways* of understanding scientific concepts as they relate to real-world phenomena. Crosscutting concepts are not taught in isolation, but continually developed in conjunction with disciplinary core ideas and science and engineering practices as students explore, explain, and make sense of phenomena at increasing levels of sophistication within units, across units, and across grades. For further information, including sample prompts and responses for each of the crosscutting concepts to support instruction and the development of formative and summative assessment performance tasks, refer to *Using Crosscutting Concepts to Promote Student Responses* developed by the CCSSO Science SCASS Committee on Classroom Assessment.

10.1 Crosscutting concepts are continuously integrated with the other two dimensions in ways that students recognize are relevant and useful to the context of the unit.

To support the teaching and learning of three-dimensional science understanding, instructional materials maintain the interconnectedness of the crosscutting concepts with the disciplinary core ideas and science and engineering practices consistently through the units. The crosscutting concepts are not additional content or information that students need to learn separately, but used as a way of thinking about and understanding the disciplinary core ideas and science and engineering practices in relationship to the phenomena under study.

10.1.1. Instructional materials intentionally integrate instruction of the crosscutting concepts with instruction on disciplinary core ideas, science and engineering practices, and phenomena.

a. Storylines for units and lessons make students aware of the crosscutting concepts they are learning about and using to address the anchor phenomena, in the same manner and to the same degree that they make students aware of the disciplinary core ideas and science and engineering practices they are learning.

b. Lessons are designed such that the teacher and students use the language of one or more crosscutting concepts each time they discuss how a disciplinary core idea relates to a phenomenon (as part of classroom dialogue, writing prompts, peer feedback, or assessments). At minimum, students are asked to reason with at least one crosscutting concept in each set of lessons.

c. When appropriate, lessons or tasks are designed to feature how the crosscutting helps students see the connection between a disciplinary core idea and the phenomenon or to connect different disciplinary core ideas or phenomena together. Language such as *"related to"* or *"applied to"* is used often for structuring classroom discussions, writing prompts, modeling activities, and assessment tasks. One type of formative or summative assessment task that may be used in each unit is to ask students to engage in a practice (model, explain, argue, analyze, question) to express the relationship between a disciplinary core idea and a phenomenon in two or three different ways using different crosscutting concepts (for example, first with patterns, then with cause and effect, then with energy and matter).

10.1.2. Instructional materials avoid common pitfalls with integrating crosscutting concepts as part of three-dimensional learning.

a. All lesson sets include a reference, discussion, or activity involving at least one of the crosscutting concepts. While a crosscutting concept is not the focus of each lesson, instructional materials prompt both teachers and students to think about and apply the crosscutting concepts to phenomena and disciplinary core ideas.

b. Crosscutting concepts are part of the storyline that students are figuring out as they work through the unit. Instructional materials do not ask or direct students to think about any of the crosscutting concepts without some explicit attention, instruction, or scaffolding. This support is present yet sensitive to where the activity is situated with respect to prior instruction, and is flexibly responsive to student learning needs. Sources of support include educative features, supplemental resources, and instructional moves integrated into the lesson.

c. Units do not include a "mini-lesson" or a stand-alone section on each crosscutting concept. Instead, they introduce and reinforce the development of crosscutting concept understanding in the context of the problem or scenario students are working on.

10.2 Students experience an increase in the sophistication and complexity of their understanding of all crosscutting concepts across units and grades in an identifiable and planned manner.

Students' three-dimensional understanding of science is developed in ways that increase in sophistication and complexity across units and grades with an intentional and visible plan. The introduction and development of each of the seven crosscutting concepts across units and grades reflects this overall commitment. Each crosscutting concept is distinct with its own learning trajectory for the middle grades. Instructional materials help teachers and students see and understand these learning trajectories, and provide visible and intentional opportunities for student to demonstrate changes in their learning of each crosscutting concept across units.

10.2.1. The sophistication and complexity of crosscutting concept understanding increases across units and grades based on the descriptions of the crosscutting concept learning progressions provided in the NGSS Appendix G, especially the transitions between grade bands. Teacher materials map the learning trajectory for each crosscutting concept across units and grades in ways appropriate to the context and conceptual focus of the units. When appropriate, the design of activities and lessons include supports for teachers and students to recall and build from previous crosscutting concept understandings developed in prior units in. Teacher materials provide unit-level support that identifies what current student understanding of and experience with crosscutting concepts is assumed, and suggested adaptations or scaffolds for addressing situations where students may not have the assumed prior learning experiences. Instructional materials include both formative and summative assessment opportunities for students to demonstrate and document their current understanding of each crosscutting concept over the course of a unit and across units within a year.

10.2.2. Instructional materials avoid common pitfalls with developing crosscutting concept learning trajectories over time. They do not teach a crosscutting concept only once in middle school, but rather provide multiple opportunities for students to engage with each of the seven crosscutting concepts across units at each grade level. They also do not teach each crosscutting concept the same way each time, varying the structure, routine, or template to each use of a crosscutting concept. While teachers and students are supported in using consistent language in discussion and writings about crosscutting concepts, how students are asked to think about, reason with, and apply crosscutting concepts in three-dimensional learning varies across units and grades in ways that challenge students.

10.3 Students engage in multiple crosscutting concepts in each unit, and students reason with and discuss all seven of the crosscutting concepts at each grade level.

In three-dimensional science learning, there is not just one way to relate a disciplinary core idea to a phenomenon through a practice. There are multiple ways to relate disciplinary core ideas to phenomena, and crosscutting concepts are a set of tools and resources that teachers and students use to do this. Every science concept has one (or more) of the crosscutting concepts that constitute what it means to understand that idea. Facts that can be known without crosscutting concepts are not three-dimensional and are not be the focus of instruction. Explicitly using multiple crosscutting concepts to relate disciplinary core ideas to a phenomenon (through explanations or models) makes the crosscutting concepts a powerful dimension for students, and can make the robustness of their scientific reasoning and understanding visible to both teachers and peers.

10.3.1. Students engage with multiple crosscutting concepts in each unit. Activities and lessons guide teachers and students to reason about the anchoring phenomena in different ways. When possible, there are at least two opportunities in a unit for students to think about the anchoring phenomenon and other phenomena in ways that are similar to how scientists would draw on different perspectives to explain the same thing. Each of these perspectives should use a different crosscutting concept to reason about the phenomenon. As student learning progresses across units, materials are designed so that students take more responsibility and ownership for considering phenomena using different crosscutting concept perspectives. In early units, activities are clearly specified and closely scaffolded to provide students with support for thinking from multiple perspectives. Later units provide less structured tasks and more open opportunities for students to engage in this kind of relational sense-making around constructing explanations or solving problems around phenomena, both individually and socially in groups or as a whole class.

10.3.2. Instructional materials avoid common pitfalls with engaging students with multiple crosscutting concepts around phenomena. They avoid aligning a single crosscutting concept to a disciplinary core idea or anchoring phenomena. While a lesson set might focus more explicitly on developing one crosscutting concept, there are opportunities in the unit for students to consider other crosscutting concept perspectives on that same idea or phenomenon. Activities do not ask students to apply a crosscutting concept without some form of responsive instructional supports or scaffolding.

10.4 Students use consistent language of crosscutting concepts in all units, particularly when discussing phenomena and engaging in science practices.

Crosscutting concepts are not seven distinctly different, unrelated ideas. Together, they are a set of resources to support scientific reasoning and meaning making. Crosscutting concepts are also central to communicating science (between peers or between student and teacher, verbally or written). To help students understand the role that all of the crosscutting concepts play in supporting reasoning and meaning-making, instructional materials use common language when discussing crosscutting concepts.

10.4.1. Instructional materials use consistent language about crosscutting concepts within and across activities, lessons, and units to support students' developing understanding and application of crosscutting concepts.

a. When students discuss phenomena, they use the language of crosscutting concepts as a lens or a way of "looking at" or "seeing what's going on". For example, materials can provide supports, models, or scaffolds for students to talk about seeing a system or recognizing a pattern in a phenomenon or experiment.
b. When students are establishing and articulating relationships between disciplinary core ideas and phenomena or to other disciplinary core ideas, they use the language of the crosscutting concepts as a bridge or connector to make the relationship visible and salient. For example, instructional materials support students to write initial explanations for an unexpected event by connecting the observed causes and effects to science ideas they learned about before.
c. When students are engaging in science practices, they use the language of the crosscutting concepts as tools to encourage engagement in more meaningful ways. Materials use features of the crosscutting concepts as prompts to structure classroom dialogue or written responses as students engage in the different practices. Asking students to be clear about how the crosscutting concepts are used in the science and engineering practices builds these concepts into powerful tools, and provides common language for students to discuss and share ideas when collaborating in the practices.
d. When the class is figuring out how to organize concepts or relate seemingly disparate phenomena to each other, students use the language of crosscutting concepts as rules to help students organize and categorize their understanding. This is a way to make the big ideas visible for students that can often get lost when focused on individual examples of phenomena. Students and teachers can use the language of crosscutting concepts as rules towards the end of a unit or set of investigations to place new insights and understandings in the context of the broader disciplinary core ideas that are developed across units and grades.

11–Classroom Routines

Classroom routines are activity structures that students engage in repeatedly over the course of a year and across multiple years to serve several goals. Structured routines with discrete steps that have explicit goals can serve as scaffolds for students to learn sophisticated scientific or engineering practices. They can support the establishment and maintenance of a classroom culture by providing norms and expectations about behavior and social interaction. Routines contribute to efficient use of time because once students have learned a routine, they can begin the work with minimal direction and focus their attention on the work of the routine rather than how to do the work. In OpenSciEd instructional materials, routines serve all of these goals. These design specifications address five key issues, all of which are complementary and draw on the instructional model for three-dimensional learning.

11.1 Instructional materials draw out student questions and identification of problems and use them to guide the ongoing science work of the class.

Instructional materials support students in developing public representations of their thinking, progress, and questions. They elicit current student understanding throughout the unit, and attend to navigation and coherence from the student's perspective.

11.1.1. Units provide multiple opportunities for public representations of student questions. At the opening of a unit, and as students make progress on models and designs, lessons provide opportunities for students to raise questions about phenomena or to inform design solutions. A driving question board is an example of a public repository for students' questions created within the first few lessons and updated throughout the unit. All units use comparable routines to compile and track questions about phenomena and designs. Lessons include supports for teachers to work with students to connect to the questions students have generated to motivate the work and to monitor progress.

11.1.2. Instructional materials support students in generating questions by eliciting students' current understanding about phenomena and problems and asking them to make sense of the phenomena, generate ideas about how to solve a problem, and connect the phenomena or problem to their own experiences.

11.2 Routines support students in tracking the flow of progress and the current explanations, models, or designs.

11.2.1. Instructional materials include opportunities for public representation of the flow and progress of lessons. The class records their progress in a public representation (such as a model tracker or summary table) that includes the lesson question or purpose, phenomenon, and what they figured out. Each lesson or set of lessons includes a discussion-based activity to update the model tracker representation. Individual students also keep a version of this representation in their notebooks.

11.2.2. Instructional materials include opportunities to create and update public representations of scientific models. Units contain frequent opportunities for students to revise their models, first as individuals or pairs, and then in small groups. At key points when enough evidence has been accumulated, a lesson provides an opportunity for students to compare their models in small groups and attempt to reach consensus. Following the small group consensus-building process, the whole class should develop a class consensus model through discussion, and create a shared, public representation of it.

11.2.3. Teacher materials guide teachers in eliciting current student understanding at key points in the unit (not just prior knowledge at the beginning) so that teachers are aware of the resources that students have drawn on when reasoning about a phenomenon or problem. When teachers elicit and connect to current understanding, students are more likely to experience instruction as coherent and are able to track their progress over time.

11.3 Instructional materials involve students in discussions about how to move from one lesson to the next in the storyline (navigation).

11.3.1. Student questions are key to the navigation and coherence from the students' perspective because they provide a clear purpose that links one activity to another. Throughout the units, lessons prompt teachers to bring students back at regular intervals to the record of questions to determine which ones have been addressed, which haven't and to determine if there are new questions.

11.3.2. Transitions between lessons in units (at the closing of a lesson, the opening of the next lesson, or both) contain whole class navigation discussions to maintain coherence from the students' perspective. The discussions have both a reflective and a prospective element. The reflective element asks students to articulate the question or problem for the lesson and the way the class decided to investigate it and what they figured out, referencing public representations such as a summary table or model tracker. The prospective element involves asking students to evaluate their current progress, and discuss possible next steps. While the flow from one lesson to the next is anticipated in the unit outline, these discussions involve students working as partners through the logic of where to go next, and maintain the coherence from their perspective.

11.4 Instructional materials ask students for gapless explanations.

11.4.1. Teacher materials guide teachers in helping students to iteratively develop and evaluate their models, test them for generality, and uncover limitations that lead to productive directions for investigation.

11.4.2. Teachers are provided with discussion strategies to press students for gapless explanations and models*.* Teachers support students in linking their ideas, from a variety of sources including prior knowledge, into a coherent chain of reasoning which ultimately allows students to put those pieces together into a causal explanation or complete solution to a problem. Instructional materials contain guidelines students can use to evaluate the coherence and completeness of models, and of explanations derived from models.

11.4.3. Units contain sequences of phenomena selected to help students develop explanatory models, and then uncover questions that lead to either generalizing the model or elaborating it to handle the new cases. For example, after figuring out that instruments and speakers appear to make sound by vibration, students ask whether all objects that make a sound (including very solid objects like floors, walls, and tables) vibrate when they make a sound.

11.5 Teachers are guided in developing and maintaining classroom norms that support student engagement in the science and engineering practices through productive talk.

11.5.1. Teacher materials provide supports for teachers to engage students in science and engineering practices through whole class discussion. Teacher supports provide example prompts and strategies to support students making their thinking public, building on ideas of others, and supporting models, explanations, and designs with argument. Example approaches include supports for science talk moves.

11.5.2. Instructional materials provide supports for teachers to establish classroom norms that support three-dimensional learning, including going public with one's thinking, respectfully questioning ideas, listening to others and building on their ideas, continued testing of the generality and limitations of candidate models, and supporting models and explanations with empirical evidence.

11.5.3. Instructional materials include whole class discussion activity structures used to support productive science talk, such as scientist circles.

12–Integration of English Language Arts and Mathematics

Instructional materials integrate English Language Arts through the literacy practices of reading, writing, and communication, and mathematics, to develop and reinforce important science ideas and practices. Students are supported in strengthening their literacy and mathematics practices and thinking, and in demonstrating the importance of these practices for science.

12.1 Support for integrating English language arts into science classrooms is provided.

The goal of integrating English language arts within units is to use literacy practices of reading, writing, and communication to develop and reinforce important science ideas and practices, while supporting students in strengthening their English language arts practices and demonstrating the importance of language practices for science.

12.1.1 Instructional materials are intentional in their placement and purpose of text. Text is placed within the unit at key junctures where students need to gather information to motivate the storyline, better understand a concept, or work through an investigation. Generally, students experience a concept in some way prior to reading about it, allowing them to make a connection between their experience of a concept and scientific information in the text. Text that introduces a phenomenon to students is adapted for classroom use and intended to engage students into the storyline (for example, a doctor's note, an abstract and methodology section from a study, or field observations). Some text is just-in-time to help the storyline along, to generate questions or ideas from students, to help to clarify some piece of the puzzle students are figuring out, or to give students language to describe what they are seeing. Text features people of different ages, genders, cultures, abilities, and racial and ethnic groups engaged in the scientific enterprise, and include individuals with different perspectives, working toward similar or different purposes, as part of different disciplines and communities (such as citizen scientists, families, or classmates).

12.1.2 Instructional materials are intentional in the variety and complexity of text. Units include text from a variety of sources that require students to interpret key science ideas from the text (such as words, graphs, images, and other media). Instructional materials include a balanced mix of authentic science sources adapted for classroom use, and custom fictional, historical, and informational texts matched to the storyline of the unit. Students access multiple sources so that they can evaluate audience, purpose, and tone. Text is aligned appropriately to grade level and text complexity and matches the learning goals of the activity. Some texts may vary in length and complexity, but should be intended to push the storyline forward.

12.1.3 Students analyze texts using strategies drawn from *Common Core State Standards*. Students cite specific textual evidence to support analysis of science and technical texts; determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions; follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context; analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic; analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text; integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (such as a flowchart, diagram, model, graph, or table); distinguish among facts, reasoned judgment based on research findings, and speculation in a text; and compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic.

12.1.4 Instructional materials are intentional about the purpose, placement, and variety of written work. Units incorporate a student science notebook and additional written student work on a daily basis for students to write, draw, and communicate their understanding of science ideas and practices. Written work integrates standards for writing from the *Common Core State Standards*, and instructional materials ask students to articulate claims and arguments, cite evidence from their own work and scientific sources, and evaluate the claims and counterclaims of others. Students draw upon a variety of texts and analyze graphs, tables, and images as part of writing development.

12.1.5 Where appropriate, teacher materials provide support and modifications for students with special learning needs, such as English learners or students with reading or writing accommodations. For example, they may provide modified texts at lower reading levels or sentence starters and sentence frames to guide the development of verbal or written work.

12.1.6 Students are frequently engaged in speaking, listening, and responding to others as part of their participation in scientific and engineering practices. Materials provide guidance and rubrics aligned to *Common Core State Standards* for speaking and listening, including standards for comprehension and collaboration, and presentation of knowledge and ideas. Students frequently engage in peer-to-peer discussion to share, express, and refine their thinking based on new information. They develop, present, and defend their ideas to one another, verbally, in written forms, and in expressive forms in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details.

12.2 Support for the integration of mathematics into science classrooms is provided.

The goal of integrating mathematics within units is to use mathematical understanding and practices to develop and reinforce important science ideas and practices, while supporting students in strengthening their math understanding and practices, and demonstrating the importance of mathematical thinking and practices to science.

12.2.1 Instructional materials are intentional in their placement and purpose of mathematics. Mathematics is intended to help the storyline along, to help to clarify some piece of the puzzle students are figuring out, or to give students tools to highlight, analyze, and interpret important patterns in the data they are exploring. When applying mathematics, materials connect to and reinforce the *Common Core State Standards for Mathematics*. Mathematical analysis is not be used in isolation of developing understanding of the target science ideas.

12.2.2 The variety and complexity of mathematics is intentional, and instructional materials include a variety of mathematical representations and ideas. Mathematical analysis is accessible for all students and provides them with a deeper understanding or speeds up insights into qualitative patterns in data for needed understanding of the target science ideas. Analysis that detracts students from the science storyline or slows down the pace at which students are developing insights into the patterns in data or qualitative relationships necessary for understanding of the target science ideas is avoided. Where mathematical analysis is part of an investigation, multiple models, representations, and ways of interpreting the data are supported. Teacher supports are provided for leveraging multiple ways of student thinking, connecting, and representing their mathematical ideas, both in investigations that are targeting the use of those mathematical ideas and in those where it is likely that some students may bring them in.

12.2.3 Instructional materials integrate mathematical understanding and practices that are grade-level appropriate across both math and science standards. They align to the development of the mathematical topics in the *Common Core State Standards for Mathematics,* and do not require or attempt to teach them before they have been addressed in the *Common Core*. For example, statistical measures of center are not introduced until Grade 6 and probability is not addressed until Grade 7. Documentation is included in all materials to indicate alignment to the *Common Core* and to alert teachers for opportunities to attend to the connections.

12.2.4 Where appropriate, teacher materials provide support and modifications for students with special learning needs related to mathematics. For example, they may provide alternate students prompts to provide opportunities for students to engage with the mathematics qualitatively rather than quantitatively. Instructional materials embed scaffolds to help students break down the use of mathematics into manageable parts and use multiple representations and manipulatives of mathematics concepts to help reinforce mathematical concepts or reasoning. Where possible, teacher materials provide support to break down analysis of the data into smaller steps or explain the problem in a different way.

13–Meeting Practical Needs and Constraints of Public Education

An important risk in efforts to transform educational practices and improve outcomes is to overlook the importance of *practicality.* In the rush to incorporate attributes that are known to support transformation and improvement, programs must make sure that it is practically possible and realistic for teachers to implement in order to bring about real and lasting change. Practicality is contextual. The thresholds for what makes a program too challenging or infeasible depend on the social capital and material resources that are available in a particular setting. Therefore, the design specifications for practicality have been designed in consultation with core state partners to fit the contexts in their states.

13.1 Instructional materials help teachers plan and implement coherent three-dimensional learning experiences for all students in every activity.

Teachers need supports to help them plan and implement their NGSS designed instruction across an activity, lesson, or unit, and effective supports are needed to help teachers successfully engage their students in three-dimensional learning. Students need materials that support their own engagement in three-dimensional learning in every activity across a unit. OpenSciEd seeks to provide the necessary instructional materials to help teachers plan and implement a coherent three-dimensional learning experience for all students in every activity.

13.1.1. Instructional materials use a consistent structure for units, consisting of a four-level hierarchy (*units* made up of *lesson sets*, made up of *lessons*, made up of *activities*) with information provided to teachers at each level.

13.1.2. Teacher materials provide instructional supports for planning and implementing an activity or lesson, and for different goals and outcomes, while foregrounding the interconnected role of phenomena, practices, disciplinary core ideas, and crosscutting concepts in the students' sense making.

13.1.3. Instructional materials provide educators with presentations for use in classrooms (class-facing slides) that are easily editable and adaptable to local contexts. They also include activity guides and readings for students.

13.2 Instructional materials include meaningful optional learning opportunities after specific points in a unit to motivate students to think, talk, and explore outside of school.

Home learning provides a vehicle to extend student thinking beyond the time they spend in class. Meaningful home learning helps students develop, build on, or extend learning from the classroom. It should be tightly connected to the learning goals, but also compelling and motivating for students to think about, talk about, and explore outside of the bounds of school with their family, friends, or other people they interact with throughout the day. OpenSciEd seeks to provide meaningful, *optional* home learning opportunities for teachers to use flexibly in their classroom, after specific points in an instructional unit.

13.2.1. The purpose of home learning is to provide students opportunities to learn more about how science ideas developed in class can be used to make sense of additional phenomena and problems in their lives and in their communities; to provide new contexts for students to extend their interest, curiosity, and creativity about what they have figured out in class; and to provide a venue for students to engage in discourse with other people in their lives about what they are wondering, thinking, and figuring out related to the experiences in the classroom.

13.2.2. The structure of home learning opportunities might include framing around a small number of compelling questions, relevant connections to real world examples, protocols for students to engage in or to explore additional phenomena first hand, concise background information and text, simplified (but not oversimplified) data and protocols, scaffolds for supporting the development of student thinking across an assignment around one big idea, prompts designed to help student raise new questions (leaving them more curious at the end of the assignment than when they started it), and suggestions to help spark student interest in initiating or participating in a conversation about what they are doing or figuring out with other people.

13.2.3. Instructional materials provide at least five optional opportunities for home learning per unit. Teacher materials provide specific guidance on how to follow up on and connect to students' findings, ideas, and questions raised in the assignment to subsequent discussions in future lessons. Example "alternate prompts" and "expected students responses" are included to help students make connections for cases where the class or student didn't complete the assignment.

13.3 Teachers are guided in using student work for grades while also providing meaningful feedback to students about their learning.

Each district and school has varying needs for grading that cannot all be addressed in the instructional materials. However, teacher materials provide guidance on which student work products could be graded and also the appropriate supports to do such grading. This approach allows educators to choose what to grade based on the needs of their classroom and their district. Teacher materials provide the necessary supports to educators to use student work for grading purposes while also providing meaningful feedback to students about their learning.

13.3.1. Teacher materials provide a list of grading opportunities that include the intended purpose of the student work and how the work can be used to determine a grade (in particular if there are no right or wrong answers) by providing ideal student responses and examples of incorrect student responses, and clear answer keys, rubrics, and scoring guidance that is aligned to those tools.

13.3.2. Teacher materials identify grading opportunities approximately every other day of instruction and at least one major grading opportunity at the culmination of the unit. While there might be more frequent opportunities, regular checkpoints provided at allow teachers to determine student progress. Teachers may choose to use these opportunities as grading opportunities depending on their district or school policy.

13.3.3. Teachers are supported in sufficient detail to understand why answers are graded in such a way and how those answers could be improved so that both teachers and students can have meaningful feedback from the grading opportunity.

13.4 Instructional materials are provided in a convenient form that is useable by the largest possible audience.

Instructional materials are convenient and useable by the largest possible audience.

13.4.1. Student print materials consist of a full-color, non-consumable student edition and a set of black-and-white, consumable student handouts to be distributed for students to write on. Digital versions are also available. Students are provided or asked to supply a science notebook as a persistent space for them to record and organize their work.

13.4.2. Teacher print materials consist of a full-color teacher guide that is bound to lay flat. Teachers are also provided a digital version formatted for a laptop or tablet that supports printing. Teacher materials include presentation slides for each lesson to help with structuring discussions and activities.

13.5 Computational technology supports three-dimensional science learning, within school constraints.

Instructional materials seek to take advantage of the benefits of computational technology to support three-dimensional science learning, while conforming to the practical constraints of current schools.

13.5.1. Instructional materials assume that every classroom has a dedicated computer that can project on a screen or display that is large enough for the entire class to see, and has an internet connection that is fast enough to support video streaming. The instructional materials may call for interactive use of computers by students in a ratio of 2 students per computer, as long as those activities can also be done as a whole class on the dedicated classroom computer.

13.5.2. To accommodate teachers who need to schedule laptop carts or computer labs, interactive activities require no more than 2 consecutive class periods of instruction and are scheduled so that they don't require more than two out of every ten instructional periods.

13.6 Students are provided with the greatest possible opportunity to engage in scientific and engineering practices with appropriate tools and techniques, within school constraints.

Instructional materials seek to provide students with the greatest possible opportunity to engage in scientific and engineering practices with appropriate tools and techniques, within the practical constraints of current schools.

13.6.1. Instructional materials assume that every teacher has space in the classroom where students can conduct hands-on activities that require table or counter space of 18" by 24" inches for every group of 2 to 4 students.

13.6.2. Instructional materials assume that every teacher has access to standard middle school laboratory equipment (glassware, microscopes, balances) for every group of 2 to 4 students.

13.6.3. Instructional materials may require consumable supplies and non-standard equipment that can be purchased for less than $400 for 6 sections per unit on average. The cost of replenishable supplies to implement a unit in subsequent years average less than $80 for 6 sections each year.

14–Guidance on Modifying Instructional Units

OpenSciEd instructional materials are designed as an Open Educational Resource with the explicit goal of supporting the adaptation and customization of the program for different goals and circumstances. As the design includes building understanding and abilities over time, the units and the lessons within units are intended to be taught in a specific order. Modifications to the sequence of units or the contents of units could undermine the design.

To enable others to adapt or customize the program without undermining the design, guidance is provided to those who might modify the units. Teachers and curriculum coordinators are made aware of the implications of potential changes and are provided with information that will allow them to make changes in a way that still achieves the goals of the program. Teacher materials provide a clear rationale behind the sequence and design of materials in the program. Informing educators of this rationale helps to avoid modifying the materials in ways that are detrimental to student learning. Teacher materials also provide teachers with information about pacing of the materials (including where activities could be compressed or extended) to help with avoiding a break down in the storyline for students. Information on which learning goals are emphasized at key parts of the materials allows teachers to make informed decisions about supplementing materials or customizing those materials for a particular student audience.

14.1 Support for modifying unit sequences is provided.

14.1.1. To allow educators to change the sequencing of units instructional materials document how concepts and practices are developed over time and across units. This documentation provides information about how a unit depends on previous units and how it supports subsequent units, about the prerequisite knowledge necessary for each unit and what actions are necessary to supplement this knowledge if the unit is taught out of the preferred sequence, and about how future units may be impacted if the unit changes in the sequence.

14.1.2. Instructional materials provide guidance about making slight changes to the sequence to increase or decrease the instructional time for the unit. This includes places in the unit where instructional time can be shortened or activities can be eliminated without compromising the learning goals for the unit.

14.2 Support for modifying unit storylines is provided.

14.2.1. To allow educators to customize the storyline for specific locations or populations, instructional materials document how the central task connects the learning goals of individual activities into a coherent storyline.

14.2.2. Units include and document opportunities to locally frame the phenomena or design problems for students and to continually make connections to the students' lived experiences in their community.

14.3 Support for modifying activities is provided.

14.3.1. To allow educators to modify or replace individual activities, instructional materials document the learning goals for each activity. Learning goals for each lesson are clearly stated within the teacher materials, allowing educators to determine whether switching or supplementing the lesson with a different activity is appropriate or not.

Credits

The chapters in this volume were developed by collaborative teams. Each team had one or two designated leads and several members selected for their expertise by OpenSciEd Developer Consortium and State Steering Committee members. Their work was coordinated by Daniel Edelson and Audrey Mohan. Final editing was conducted by OpenSciEd.

Chapters 1 *Instructional Model* and 11 *Classroom Routines*

Brian Reiser, Lead
T.J. McKenna
Cynthia Passmore
Pam Pelletier
Mark Windschitl

Chapter 2 *Equitable Science Instruction for All Students*

Philip Bell, Lead
Megan Bang
Cory Buxton
Michael Heinz
Okhee Lee
Deb Morrison
Alberto Rodriguez
Enrique (Henry) Suárez
Gina Tesoriero
Carrie Tzou

Chapter 3 *Assessment to Inform Teaching and Learning*

Amelia Gotwals, Lead
Dante Cisterna
Savitha Moorthy
Emily Pohlonski
Megan Schrauben

Tamara Smolek

Chapter 4 ***Designing Educative Features***

Elizabeth A. Davis, Lead
Katherine McNeill, Lead
Janet Carlson
Kris Grymonpré
Katherine Barnett Rivas
P. Sean Smith

Chapters 5 ***Asking Questions and Defining Problems*** **and 6** ***Planning and Carrying Out Investigations***

Barbara Hug, Lead
Idit Adler, Lead
Christina Krist
Samantha Lindgren
Brian MacNevin
William Paddock III
David Stroupe

Chapter 7 ***Developing and Using Models, Constructing Explanations, and Designing Solutions***

Cynthia Passmore, Lead
Ron Gray
Samuel Hindi
Sinead Klement
Mechelle La Lanne

Chapter 8 ***Analyzing and Interpreting Data and Using Mathematical and Computational Thinking***

Michelle Wilkerson, Lead
Corey Brady
Shafiq Chaudhary

Victor Lee
Ananda Marin
Mayumi Shinohara

Chapter 9 ***Arguing from Evidence and Obtaining, Evaluating, and Communicating Information***

Leema Berland, Lead
Leah Bricker, Lead
Amy Deller-Antieau
María González-Howard
Breigh Rhodes
Christopher Wright

Chapter 10 ***Crosscutting Concepts***[1]

Ann Rivet, Lead
Dora Kastel

Chapter 12 ***Integration of English Language Arts and Mathematics,*** **and**
Chapter 13 ***Meeting Practical Needs and Constraints of Public Education,*** **and**
Chapter 14 ***Guidance on Modifying Instructional Units***

Audrey Mohan, Lead
Michael Novak, Lead
Daniel Edelson

[1] The work that resulted in this product was supported by the National Science Foundation. The opinions and positions asserted here are of the author only and do not necessarily reflect the views of the National Science Foundation.