Critical Features of Instructional Materials Design for Today's Science Standards

A Resource for Science Curriculum Developers and the Education Field

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Introduction

Today's science standards, including the Next Generation Science Standards (NGSS), have initiated a significant shift in all parts of the science education system. As a result, science instructional materials are also changing. Educators—including school and district administrators — and developers of instructional materials are working to anticipate and overcome common challenges to creating, selecting and implementing high-quality curricula. EdReports and NextGenScience are leaders in the science education field and provide evaluations of the alignment of science and engineering instructional materials to current science standards using the EdReports science review tools and the EQuIP Rubric for Science, respectively. The organizations co-developed this resource to illustrate and provide unified definitions of design features that ensure instructional materials can help students meet or exceed today's science standards.

The NGSS was introduced in 2013, and has been adopted in 20 states, with another 24 states having developed standards based on the NGSS (and/or *A Framework for K–12 Science Education*). Eight years later, curriculum developers and classroom educators are still working to design and adapt materials that fully incorporate the critical features of these standards. The complexity of this work is reflected in the reviews conducted by the authors of this resource: only about three percent of materials submitted to the NextGenScience Peer Review Panel for review have earned the NGSS Design Badge, and only one science program, thus far, has earned EdReports' "Meets Expectations" rating for standards alignment. However, the percentage of high-quality materials is growing and materials are increasingly incorporating one or more of the critical features described in this document.

EdReports and NextGenScience have documented the successes and challenges faced by curriculum developers and by educators. These efforts have clarified the design features that are the most challenging to articulate as well as those that are most critical to incorporate in order to achieve high-quality, standards-aligned science curriculum.

This resource leverages years of expertise from reviewing K–12 science instructional materials to describe trends on what to look for when designing or selecting materials to ensure students and teachers have curricula that meet the full intent of the NGSS. School districts and states will also benefit from the information in this resource as they navigate the selection, adoption, and adaptation of high-quality instructional materials. They play a pivotal role in creating the demand for any developer of science content to incorporate critical NGSS features to meet local needs, including the expectations of their state standards.

The critical features described in this document are based on approaches to science learning and assessment described in *A Framework for K–12 Science Education* and subsequent research. As an example, one key shift is the focus of instruction from learning about an isolated science topic to *figuring out* a contextualized phenomenon or problem using science ideas and practices. These innovations require significantly different content and instructional design than was needed to meet previous sets of standards. A foundational understanding of these educational innovations is necessary for users of this document. For details about the innovations of today's science standards and why they are critical for students, see *NGSS Innovations and Instructional Materials*. Introductory information on the background and structure of the standards is available here.

Importance of Critical Features in Instructional Materials

One of the most important factors for ensuring that all students experience science education that prepares them for future success is access to high-quality, standards-aligned instructional materials. This is especially critical for our nation's Black, Latinx, multilingual, and low-income students.

Research indicates that all teachers, no matter their experience level, can benefit from using high-quality, aligned materials. A 2017 study provided evidence that the effect of high-quality curricula on learning is the same as moving an average performing teacher to one at the 80th percentile. Improving the quality of curriculum can also be 40 times more cost effective than class-size reduction. Perhaps most importantly, providing teachers with coherent, student-centered instructional materials means that they no longer need to spend more than 12 hours a week creating lessons from scratch or scouring the internet for lessons — practices that produce low-quality results that disproportionately affect students of color and those experiencing poverty. Instead, when teachers have a foundation of high-quality content to work from, they can focus their time on what they do best — bringing lessons to life and meeting the needs of individual students.

Structure of this Resource

The critical features described in this resource are grouped into three main sections: Learning Goals, Student Supports, and Student Assessments. Within each section, the critical features are described in detail, including less like/more like charts to show what is new and different about the feature as compared to common misconceptions in the field or to instructional materials designed for prior standards. Each section also illustrates the features to support those involved in development of materials and those involved in the selection and use of materials. **The authors do not intend for the illustrations to be prescriptive or restrictive.** There are many ways high-quality materials might successfully incorporate the features described in this resource. The included illustrations can provide support for districts to calibrate their expectations related to materials and facilitate conversations with those who produce the materials.

The ordering of the critical features throughout this resource does not indicate relative importance or a linear process of curriculum development. Instead, the critical features are grouped by related themes, which vary in scope. Curriculum development and revision is a complex process that can take many different forms, so this document is intended to be used in any order that is helpful to the reader.

Our Process

The EdReports and NextGenScience teams developed this resource in collaboration to provide unified guidance to the field. The development process included:

- **Initial Analysis.** EdReports and Next GenScience conducted a comprehensive analysis of hundreds of the materials reviews over the past few years, includ ing from unpublished reviews, identifying trends in review data and high-impact areas of improvement for curriculum materials.
- **Collaborative Understanding.** Based on the analysis of prior reviews, EdReports and NextGenScience identified critical features for the field.
- **Development of Draft Product.** The teams developed descriptions of the critical features and illustrated potential approach es developers could take for each feature.
- **Stakeholder Review.** The product was reviewed by a collection of stakeholders in the field, including those with expertise in curriculum development, materials review, and material selection, who provided feed back on the degree to which this resource 1) clarifies expectations for materials and 2) aligns with the best and current under standing about what really matters in science instruction.
- **Revision and Finalization.** Based on stakeholder reviews, the team revised the resource and finalized it for publication.

Section I: Learning Goals

> **Curricula based on the framework and resulting standards should integrate the three dimensions — scientific and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs) — and follow the progressions articulated in this report.**
>
> *A Framework for K–12 Science Education*

Knowing where you're going and how you'll get there is essential to getting to the right destination. This is a critical requirement of high-quality science and engineering instructional materials, which follow the specifications of *A Framework for K-12 Science Education* (the *Framework*), to lay out students' destinations (three-dimensional learning goals) and the routes by which students will be supported to reach these goals. As facilitators of student learning, educators need to have materials that clearly articulate where students are going and how to support them as they make progress along the route.

High-quality materials designed for today's science standards, such as the NGSS, include three critical features related to learning goals.

STUDENT SUPPORTS CRITICAL FEATURES

Critical Feature 1.1: Specifying the structure and content of the learning goals. Materials clearly describe three-dimensional, grade-appropriate learning goals that match what students learn during instruction.

Critical Feature 1.2: Describing the development of learning over time. Learning goals are presented in a coherent sequence and describe for teachers the way instruction will help students reach these goals (i.e., the learning progression). These progressions include the prerequisite learning, how learning builds within a lesson or unit, and how learning builds across units or grade levels, if applicable.

Critical Feature 1.3: Supporting students to reach all performance expectations in a grade or grade band. Materials include an appropriate number of learning goals such that students will have enough time to meet or exceed all standards by the end of the grade or grade band with realistic expectations for the pace of learning (e.g., not all front loaded).

These three critical features are described in detail below. Note that the term "learning goals" in this document refers to educator-facing goals used for planning *and not* student-facing language that is focused on particular instructional contexts.

Critical Feature 1.1: Specifying the structure and content of the learning goals

LEARNING GOALS FOR TODAY'S SCIENCE STANDARDS ARE	
LESS LIKE...	**MORE LIKE...**
One- or two-dimensional. Learning goals are broad or focus only on one or two dimensions, such as disciplinary content related to the DCIs. For instance: *Students understand that pushes and pulls can have different strengths and directions.*	**Three-dimensional.** Learning goals are built from grade-appropriate elements of all three dimensions of the standards. For instance: *Students who demonstrate understanding can: Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.* • *SEP: With guidance, plan and conduct an investigation in collaboration with peers.* • *DCI: Pushes and pulls can have different strengths and directions.* • *CCC: Simple tests can be designed to gather evidence to support or refute student ideas about causes.* Individual lesson and unit learning goals do not necessarily need to match full NGSS performance expectations or state standards. They may include a different combination of the three dimensions or include a much smaller scope of student expectations, such as partial elements.
Misaligned with instruction. Stated learning goals are much broader, more complex, or different than the scope of what students learn during instruction. For instance: *Activities may only help students meet similar learning goals from a previous grade band.*	**Closely aligned with instruction.** Stated learning goals are fully supported by learning activities, including for all three dimensions at the targeted grade level.

Making three-dimensional claims. One of the most recognizable innovations of today's science standards is their three-dimensional nature. Standards are written as three-dimensional performance expectations (PEs) to communicate the critical importance of all three dimensions in preparing students for success in college, careers, and life in the 21st century. These PEs are essentially assessment targets, describing what students need to know and be able to do by the end of the grade or grade band.

> “Instructional materials need to create coherent student learning experiences that set students on a path to use and build all three dimensions over time.

This is the performance expectation. Claiming the entire PE as a learning goal assumes ***all*** elements below are also claimed.

Students who demonstrate understanding can:

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. • With guidance, plan and conduct an investigation in collaboration with peers. - - - - - - - - - - - - - - - - ***Connections to the Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Scientists use different ways to study the world.	**PS2.A: Forces and Motion** • Pushes and pulls can have different strengths and directions. • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. **PS2.B: Types of Interactions** • When objects touch or collide, they push on one another and can change motion. **PS3.C: Relationship Between Energy and Forces** • A bigger push or pull makes things speed up or slow down more quickly. *(secondary)*	**Cause and Effect** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Bulleted items are grade-appropriate “elements.” Learning goals in high-quality materials list the full or partial elements students will know and be able to use by the end of instruction.

Connections to other DCIs in kindergarten:
N/A

Articulation of DCIs across grade-levels:
3.PS2.A ; ***3.PS2.B***

Common Core State Standards Connections:
ELA/Literacy -
W.K.7 Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-PS2-1)
Mathematics -
MP.2 Reason abstractly and quantitatively. *(K-PS2-1)*
K.MD.A.1 Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. *(K-PS2-1)*
K.MD.A.2 Directly compare two objects with a measurable attribute in common, to see which object has “more of”/”less of” the attribute, and describe the difference. (K-PS2-1)

Each of the three dimensions is written as grade band expectations for K–2, 3–5, 6–8, and high school providing significant flexibility on how and when students build proficiency over the course of the grade band. Instructional materials need to create coherent student learning experiences that set the three dimensions on a path for students to use and build over time. Therefore, in any single instructional unit, there is no expectation that students need to learn and use full PEs or even full elements of the SEPs and CCCs[1]. Three-dimensional learning goals in lessons or units may use a different combination of dimensions than specified by a PE or may cover a smaller amount of material in each dimension than described by a PE.

Supporting students to use or develop claimed goals. No matter the scope of the ultimate learning goals, it is important that they accurately indicate *what students actually learn* in the materials. This match allows teachers to have accurate expectations of student learning in each lesson as well as to be confident that the lesson will contribute to an overall program that gives students sufficient opportunities to reach or exceed all parts of the standards (see Critical Feature 1.3 below).

Since the NGSS were released, an increasing number of science instructional materials have adopted three-dimensional learning goals. However, what is still often missing from materials is a match between the claimed learning goals and what students are actually asked to do in the activities and assessments. For instance, during lesson activities, a high school-level lesson might only prompt students to "use evidence to construct an explanation," an expectation in the NGSS for grade 3–5 students, while listing the related high school SEP element as a learning goal, shown below.

Partial progression for Constructing Explanations from NGSS Appendix F

By the end of Grade 2	By the end of Grade 5	By the end of Grade 8	By the end of Grade 12
Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer reviews) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
Student prompt (below grade level) ↑ (Grade 5)			Learning goal claimed ↑ (Grade 12)

1 In most curricular programs, students are exposed to each DCI element in only one instructional unit (as opposed to many different exposures for each SEP and CCC element — see Critical Feature 1.3), so it is typically expected that students develop at least one full DCI element in each unit of instruction.

In the illustration on the previous page, the stated learning goal does not match what the lesson supports students to do because criteria for evidence used in the explanation are not given and students are not prompted to make their background assumptions clear in their reasoning. This kind of misalignment is particularly frequent for CCCs and Engineering Design DCI proficiencies. Materials often claim these components as part of three-dimensional learning goals even when there is no evidence in the materials that students have opportunities to use or learn the grade band-appropriate elements claimed. Elements of SEPs and CCCs for each grade band are listed in NGSS Appendices F and G respectively, and Appendix E shows summaries of DCIs at different grade bands to facilitate comparisons of expectations at each level.

Deliberate Remediation

During a period of transition to new standards, it may be appropriate for students to be supported to learn and apply parts of the standards below students' grade levels. However, these kinds of decisions are clearly justified and described in high-quality materials. For instance, a transitional lesson for high school students might prompt students to "use evidence to construct an explanation" and explicitly claim that students are learning and applying grade 3–5 SEP performances, explaining that this is expected to be the very first instructional unit in which these students have exposure to any SEPs due to the beginning of a transition period to new standards. In this case, the materials would describe how they will support the students to eventually become proficient in grade-appropriate SEPs.

> What is still often missing from materials is a match between the claimed learning goals and what students are actually asked to do in the activities and assessments.

Clarifying when an entire element is not addressed. It is not expected for every lesson to entirely address a completely new element from each dimension or for every unit to provide students enough experiences to become proficient in an entire PE. Several lessons or units often need to work together, providing scaffolding to help students gradually put together all the pieces necessary for proficiency in a full element or PE. In these cases, high-quality materials make this design plan clear to educators and accurately label what part of the learning is supported, identifying "missing" pieces of the element or PE that will be developed later in the unit or program rather than listing full elements or PEs as learning goals without clarification. This kind of clarification can be done in many different ways, as long as the notation is explicit to educators, including:

- Crossing out pieces of the elements that are not developed in the unit. For instance:

  "The unit helps students develop part of this SEP element: *Compare ~~and refine~~ arguments based on an evaluation of the evidence presented.*"

- Bolding the developed parts of the elements. For instance:

  "Students discuss the bolded part of this CCC element in Lesson 3: **Different patterns may be observed at each of the scales at which a system is studied** and can provide evidence for causality in explanations of phenomena."

- Making separate lists or labels for elements that are: a) fully developed, b) partially developed (e.g., only encountered once during instruction), and c) applied or reinforced from prior learning. For instance:

Applied DCI:	5.ESS1.A: *The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.* (Lesson 1) This DCI was developed in Grade 5. Students use this prior knowledge in this lesson.
Partially Developed DCI:	MS.ESS1.B: *The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.* (Lesson 2) The ideas from this DCI are briefly mentioned here and are more fully developed in Unit 4.
Fully Developed DCI:	MS.ESS1.A: *Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.* (Lessons 2–7)

Ensuring grade-appropriate targets. Keep in mind that removing portions of a targeted element may reduce its complexity and may not meet the grade-band expectations of the element, resulting in only meeting an element from a lower grade band. Therefore, it's helpful to look at how the elements progress across grade bands, paying particular attention to what distinguishes an element from the prior grade band, and ensure that is not the portion of the element cut out. (See the **Partial progression for Cause and Effect from NGSS Appendix G** table on page 10 for an illustration.)

Critical Feature 1.2: Describing the development of learning over time

BUILDING TOWARD LEARNING GOALS FOR TODAY'S SCIENCE STANDARDS IS	
LESS LIKE...	**MORE LIKE...**
Abstract. It is not evident how learning goals for activities and lessons are connected to learning goals at a broad unit or program level.	**Explicit.** Learning goals for activities and lessons explicitly describe how they build toward overall learning goals for units, and unit learning goals clearly describe how they build toward overall performance expectations for the year and grade band.
One-dimensional. These connections are only described for DCIs.	**Three-dimensional.** These descriptions are provided for *each of the three dimensions*.
Prior learning not specified. It is unclear what prior learning is required to complete activities in the learning sequence.	**Prior learning is described.** It is clear how students use and build on prior learning in the learning sequence.

Making learning progressions explicit. Science knowledge and skills build over time. High-quality materials help students develop this learning over the course of both instructional units and full programs[2], and the materials make this design clear to educators so they can look for evidence of student progress toward desired learning goals. This guidance helps ensure that each next step in the learning process is attainable but still challenging, such that students aren't left behind or bored by repetition. It also supports educators to more easily spot when students get off track and understanding the importance of each activity in the learning progression and therefore possible consequences if adjustments are made to the learning sequence.

Including progressions of all three dimensions. As high-quality materials are developed, the learning progression for each learning goal is mapped out logically and used as the foundation for instructional sequence design. Although this type of plan for DCIs is frequently incorporated into development processes in materials currently on the market, which often explicitly show how new DCIs build on top of a foundation of students' prior knowledge, it is also important for materials to describe the prerequisite skills and knowledge required to develop SEPs and CCCs, as well as how these two dimensions develop over the course of a unit. In past science education reform efforts SEPs and CCCs have often been treated as static knowledge and skills (e.g., "inquiry" skills) that students apply in an identical manner from kindergarten through grade 12, or conversely, materials reintroduce exactly the same SEP and CCC knowledge and skills in every instructional unit. Neither applying the same ideas nor repeating the same instruction will allow students to develop the deep proficiencies described for the end of grade 12 in the *Framework*.

2 A program is defined here as the full set of units for the science disciplines for a grade band: K–2, 3–5, 6–8, or 9–12.

From one grade band to another, the incremental change in student expectations for each dimension is not large *as long as students have had sufficient grade-appropriate prior learning experiences.* Each of the 25 targeted CCC elements in middle school is intended to build on foundations from the 16 grade 3–5 CCC elements, which in turn build on the 11 grade K–2 elements. As an illustration, the table below from NGSS Appendix G shows one part of the CCC K–12 progression in which students add to their understanding of the CCC in a small but significant way every three to four years:

> **It is important for materials to describe the prerequisite skills and knowledge required to develop SEPs and CCCs, as well as how these two dimensions develop over the course of a unit.**

Partial progression for Cause and Effect from NGSS Appendix G

By the end of Grade 2	By the end of Grade 5	By the end of Grade 8	By the end of Grade 12
Events have causes that generate observable patterns.	Events that occur together with regularity **might or might not be** a cause-and-effect relationship.	Relationships can be classified as causal or correlational, and **correlation does not necessarily imply causation**.	**Empirical evidence is required to differentiate** between cause and correlation and make claims about specific causes and effects.

During transition periods after new standards are adopted, students may not have had many prior opportunities to build foundational understandings. In these cases, scaffolding students to the point where they are ready to develop grade-appropriate elements will take more time. It is therefore important for teachers, administrators, and curriculum developers to clarify and differentiate expectations for transition periods versus later implementation periods when most students have pre-requisite understandings.

To help educators ensure that students are on track as they build toward new understanding for each dimension, it is helpful for materials to provide clear guidance to educators about the learning plan. The following paragraph illustrates one of many possible approaches for how materials can clearly describe the development of a middle school CCC element over the course of a unit.

> *"In Lesson 1, students apply prior knowledge that events might or might not indicate a cause-and-effect relationship to help them ask questions about the phenomenon. In Lesson 3, students are introduced to the concept of correlational relationships, and see different examples of correlational relationships that are not causal. In Lesson 4, students practice distinguishing between causal and correlational relationships as a group and discuss how this concept is useful when distinguishing between different explanations for the phenomenon. In Lesson 6, students independently distinguish between causal and correlational relationships for the first time."*

In addition to being described in a narrative, these types of progressions could be listed in a table or graphical outline format. For instance:

Lesson #	Progression building toward this CCC element: *Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.*
2	Applying prior CCC knowledge: *Events that occur together with regularity might or might not be a cause-and-effect relationship.*
3	Introduction to part of the CCC: *Correlation does not necessarily imply causation.*
6	Group practice applying part of the CCC: *Correlation does not necessarily imply causation.*
8	Student independent use of part of the CCC: *Correlation does not necessarily imply causation.*

In both formats illustrated above, the materials describe how the CCC learning goal for each lesson (e.g., introduction to part of an element, deepening understanding of an element) helps students build toward the overall unit's CCC learning goals. Note that the CCC learning goals are themselves integrated into a three-dimensional learning goal in high-quality materials, and that student activities building toward these three-dimensional learning goals are themselves frequently three-dimensional and in service of explaining phenomena or designing solutions to problems (see Critical Feature 2.4).

When considering the illustrations above, note that the number of learning activities needed to develop the element may vary based on the design of the materials and may occur within the same lesson, the same unit, across multiple units, or even across grades and with different combinations of the other two dimensions (see Critical Feature 1.3). These kinds of design decisions about how to support students to build their learning in each element are not trivial and are made differently by different curriculum materials developers.

Critical Feature 1.3: Supporting students to reach all performance expectations in a grade or grade band

SCOPE OF DEVELOPMENT OF LEARNING GOALS OF TODAY'S SCIENCE STANDARDS IS	
LESS LIKE...	**MORE LIKE...**
Limited. Insufficient learning goals are claimed for the length of instruc tion. For instance, an eight-week unit supports student development of only one three-dimensional learning goal.	**Complete.** Learning goals from each unit fit together in a program to allow student development of all grade-appropriate standards and elements of the three dimensions by the end of the grade band. Each unit in the program develops an appropriate number of elements for the size of the unit. For instance, an eight-week middle school unit might help students develop six three-dimensional learning goals.
Insufficient for SEPs and CCCs. For instance, programs only include development of each SEP and CCC element once per grade band.	**Supportive of full SEP and CCC development.** Programs provide students opportunities to experience each SEP and CCC element in multiple contexts and disciplines during each grade band.

All standards, all students. The *Framework* and today's science standards emphasize the importance of all students reaching all standards. This is essential for equity, ensuring that all students have the foundational knowledge and skills necessary to access the next level of academics and future career options. High-quality materials can promote equity by supporting students[3] to develop all required standards in each grade band. Together, learning goals for each activity, lesson, and unit need to add up to the full set of standards, preparing students for full proficiency in all performance expectations. When materials support this full scope of student learning, the pressure on educators to supplement instructional materials is reduced, allowing them to focus on meeting their students' needs.

3 Section 2 includes critical features related to instructional supports for student equity and engagement.

> High-quality materials can promote equity by supporting students to develop all required standards in each grade band.

Building proficiency in SEPs and CCCs. Learning goals in the NGSS (the performance expectations) are listed by grade level in K–5 and by grade band in 6–12. As described in Critical Feature 1.1, this means that students have at least a full year, and often three to four years to build proficiency in the performance expectations for that grade band. Most current instructional programs prioritize student proficiency in targeted DCIs in the year or grade band, but rarely attend to the importance of building student proficiency in SEPs and CCCs. As a result, very few instructional programs give students opportunities to deeply develop all of the grade-appropriate SEP and CCC elements by the end of the grade band. This often happens for one of the following three reasons:

- CCC and SEP elements are not developed at a grade-appropriate level,
- some SEP or CCC elements are used repeatedly while others are omitted, or
- students engage with a specific SEP or CCC element in only one activity without an opportunity to understand and use it deeply in multiple disciplinary contexts (e.g., life science, Earth and space science, physical science).

Multiple opportunities to learn. The *Framework* is clear that students need to experience the SEPs and CCCs in multiple contexts to develop a deep understanding of and proficiency in these dimensions and how they apply to science and engineering. This means that students need sufficient opportunities to experience each SEP and CCC element multiple times in multiple disciplines within each grade band.

For instance, in middle school, 25 CCC elements are targeted learning goals. Ideally, a three-year middle school curriculum would include a mapping of the progressions for each of these learning goals across 6th, 7th, and 8th grade and then make this design explicit to educators, showing how each element is developed and used in more than one instructional unit and integrated with the other two dimensions in a variety of ways. Each unit would then ideally contribute to the overall development process, providing students opportunities to both learn new ideas from some of the CCC elements and apply their prior learning to help deepen their understanding. As one possible approach, the table on the next page illustrates how a single CCC element might build across middle school units, integrated together with multiple SEPs and DCIs from different disciplines:

Possible development of a CCC element across Grades 6–8*: *Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.*		
Grade 6	**Grade 7**	**Grade 8**
Unit 1: Partial element introduced in a physical sciences context Unit 2: (not learned or applied) Unit 3: Partial element applied in an Earth sciences context using models Unit 4: (not learned or applied)	Unit 1: Partial element applied in a life sciences context when analyzing data Unit 2: Full element introduced, initial practice of full element in an Earth sciences context when defining problems Unit 3: (not learned or applied) Unit 4: Full element applied in a physical sciences context using computer models	Unit 1: (not learned or applied) Unit 2: Full element applied in a life sciences context when obtaining information Unit 3: Partial element applied in a physical sciences context when constructing explanations Unit 4: (not learned or applied)

*The illustration is from a middle school that uses a multi-disciplinary model for its courses, but any kind of course structure could be substituted in the illustration.

Reaching all performance expectations by the end of 12th grade will be challenging if students have not had sufficient foundational experiences with three-dimensional learning and with the development of each dimension. As more materials are designed to support this type of teaching and learning, more and more students will arrive at the next grade level with the foundational understanding in place to allow instruction to focus on grade-level appropriate learning goals.

Variability of approaches. When considering the different options to show how elements develop across multiple units and/or grades, keep in mind: 1) the number of opportunities and contexts may vary based on the organizational structure and design of the materials, and 2) in instruction and assessment, the elements of the three dimensions do not necessarily need to be combined in the same way as the performance expectations; rather, they can be mixed and matched in a variety of combinations.

Section II: Student Supports

> **Learning science depends not only on the accumulation of facts and concepts but also on the development of an identity as a competent learner of science with motivation and interest to learn more.**
>
> *A Framework for K–12 Science Education*

Student engagement is a critical factor in science and engineering learning. Therefore, ensuring that learning experiences are motivating and interesting to students is a high priority. High-quality instructional materials designed for today's science standards, such as the NGSS, support learning that is both relevant and meaningful to students and authentic to the practices of scientists and engineers. These kinds of materials include the following eight critical features, listed below under the groupings: Phenomena and Problems, Three Dimensions, and Student-Centered Instruction.

STUDENT SUPPORTS CRITICAL FEATURES

Phenomena and Problems

Critical Feature 2.1: Driving learning with a phenomenon or problem. Materials feature sense-making and problem solving with true phenomena or problems — rather than topics, concepts, or construction projects — as the focus of instruction.

Critical Feature 2.2: Matching the phenomena or problems to the DCI learning goals. Materials ensure there is alignment between the science disciplinary learning goals and what figuring out the driving phenomenon/phenomena and problem(s) would lead students to learn.

Three Dimensions

Critical Feature 2.3: Integrating learning of the three dimensions. Materials support students to both learn and use the dimensions in an integrated way, such that each dimension supports the other two.

Critical Feature 2.4: Supporting students to use all three dimensions in an integrated way to sense-make or problem solve. Materials help students to explicitly reflect on how each dimension is useful to their sense-making and problem solving.

STUDENT SUPPORTS CRITICAL FEATURES (CONTINUED)

Student-Centered Instruction

Critical Feature 2.5: Supporting students to feel as if they are driving the learning. Materi als include facilitation support, so students see that their curiosity, questions, and ideas related to prior experi ences direct the learning sequence.

Critical Feature 2.6: Sequencing lessons and units coherently and linking them togeth- er logically from the students' perspective. Students clearly see how lessons and units flow into one another in a meaningful way.

Critical Feature 2.7: Engaging students with relevant and meaningful phenomena, problems, and activities. Instructional activities as well as driving phenomena and problems are relatable, engaging, and accessible for all students.

Critical Feature 2.8: Supporting teachers to connect student assets and culture to instruction. Materials help to engage students' curiosity and participation in a way that pulls from their funds of knowledge and connects their learning to their communities and home lives.

These eight critical features are described in detail below.

Critical Feature 2.1: Driving learning with a phenomenon or problem

DRIVING LEARNING WITH PHENOMENA OR PROBLEMS IS	
LESS LIKE...	**MORE LIKE...**
Topics, concepts, or construction projects. Topics (e.g., "photosynthesis"), concepts (e.g., "trees use photosynthesis to grow") or tasks not explicitly connected to problems to solve (e.g., "build a solar powered phone charger") are used to focus learning in the materials.	**True phenomena or problems.** Phenomena (e.g., "a tree grows from a tiny seed") or problems (e.g., "I'm stuck in the middle of the desert and my phone is dead") are used to motivate student learning.
Phenomena or problems separate from learning. Explaining phenomena and designing solutions are not a part of student learning or are presented separately from "learning time" (e.g., used only as a "hook" or engagement tool, used only for enrichment or application after learning, only loosely connected to a DCI, etc.).	**Learning through phenomena or problems.** The purpose and focus of the materials are to support students in making sense of phenomena and/or designing solutions to problems as they develop and use science and engineering knowledge and practice. The entire instructional sequence drives toward this goal.

> Conceptual understanding is linked to the ability to develop explanations of phenomena and to carry out empirical investigations in order to develop or evaluate those knowledge claims.
>
> *A Framework for K–12 Science Education*

One of the major innovations of today's science standards is the idea of driving all learning with phenomena or problems (i.e., learning for the purpose of figuring something out) rather than topics or construction tasks (e.g., learning for the sake of memorizing facts, doing activities, or being "hands on"). This new kind of instructional framing gives students intrinsic motivation for learning, answering the question, "why do I need to know this?" By linking learning directly to real-world phenomena and problems, students also more readily see science and engineering as applicable and useful in their daily lives and stay focused on useful concepts rather than surface-level vocabulary.

Common challenges. An increasing number of materials reviewed by EdReports and NextGenScience include true phenomena or problems. However, in many cases, only some learning is driven by the phenomena or problems. This commonly happens for one of two reasons.

- The first lesson or two of a unit might introduce an engaging phenomenon, then the rest of the unit focuses on learning the science ideas related to that phenomenon.
- Most lessons engage students in learning about a general scientific principle, then ask students to apply the science *after learning is complete* to predict or explain a true phenomenon.

As an illustration of what it could look like to drive learning with phenomena or problems, the following two unrelated units are designed such that each lesson supports students to get a little closer to an explanation of a phenomenon or a solution to a problem.

Sample Unit A: Phenomenon-Driven Learning

Lesson 1: Students observe and ask questions about an anchor phenomenon: rivers and streams have funny shapes.

Lesson 2: Students make observations of rivers in different locations and the landforms around them, describing the patterns they see.

Lesson 3: Students test their ideas and gather data about how moving water affects the landforms.

Lesson 4: Students analyze data to conclude that water can change the shape of land and make comparisons to other landforms in pictures and text.

Lesson 5: Students describe evidence that shapes of rivers and streams were caused by water movement and draw a storyline (evidence-based account) of what happened to the landscape as the water flowed over it.

Sample Unit B: Problem-Driven Learning

Lesson 1: Students see pictures of a steep road and see a video of a woman talking about a car crash where her car brakes failed on that road. Students ask questions about why that road is particularly dangerous.

Lesson 2: Students investigate how toy cars move on different kinds of ramps to test ideas about what kind of road makes it hard for cars to stop.

Lesson 3: Students communicate their findings about what kinds of ramps make cars go the fastest and plan investigations for how to make the cars go slower.

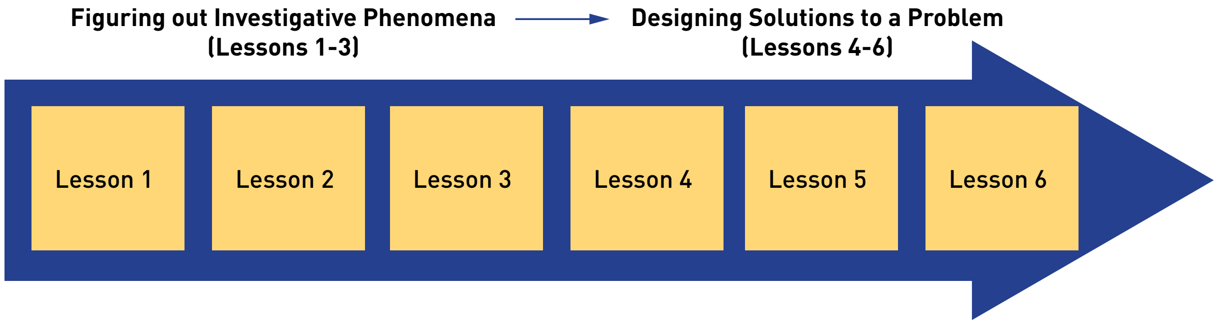
Lesson 4: Students conduct their investigations about ways to make cars go slower.

Lesson 5: Students discuss their conclusions and brainstorm road designs to solve the problem of car crashes when brakes fail.

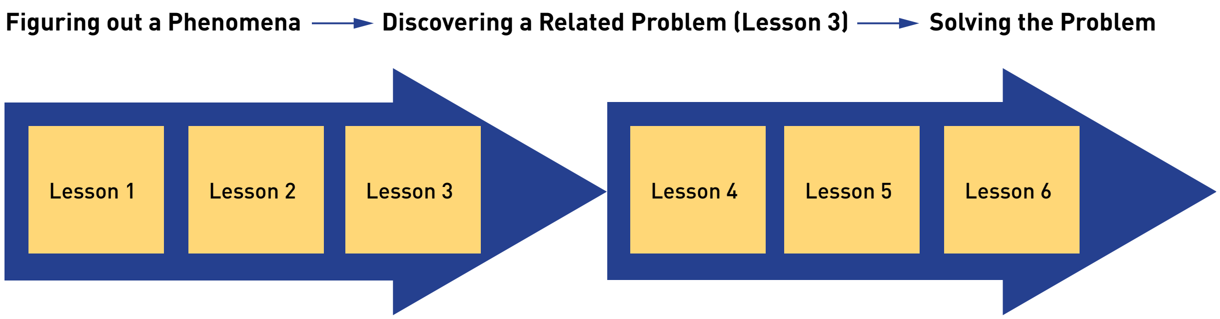
Lesson 6: Students build and test their design with ramps and toy cars.

Lesson 7: Students present their test data and compare designs to determine which best solves the problem.

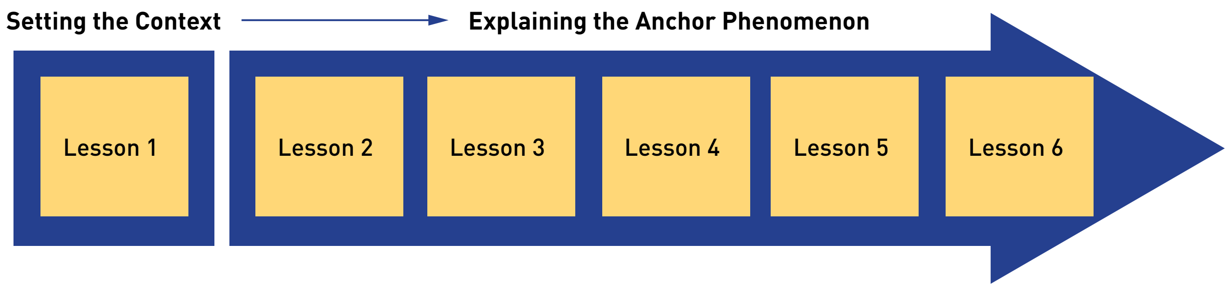
In each illustration above, one anchor phenomenon or problem was the entire focus of the unit. However, this isn't the only approach high-quality materials use to support this kind of learning. Below are a few potential structures for phenomena or problem driving learning:



Individual lessons can use smaller-scale, investigative phenomena to focus on examples related to explaining part of an anchor phenomenon or to build toward just part of a solution to a problem.



Units may also use two or more related phenomena or problems sequentially instead of one anchor phenomenon. This might look like students figuring out a phenomenon in the first half of a unit, then discovering a related problem and continuing the learning process in order to solve that problem in the second half of the unit.



In some cases, students may need context before they understand the significance of a phenomenon or problem and why it is surprising, so a phenomenon might not be introduced immediately in the beginning of Lesson 1. For instance, high school students might need to be reminded about their prior knowledge of the structure of atoms and the atomic nature of matter (mostly empty space) to realize that it is surprising that a glass of water doesn't fall through a table.

Critical Feature 2.2: Matching the phenomena or problems to the DCI learning goals

USING A PHENOMENON OR PROBLEM THAT MATCHES LEARNING GOALS IS

LESS LIKE...	MORE LIKE...
DCIs are only *related* to phenomena. The DCI learning goals are only loosely connected to the phenomenon or problem.	**DCIs *explain* phenomena.** The DCI learning goals help students explain a phenomenon or design solutions to a problem.
Extra DCIs. Students would be able to explain the phenomenon without using or developing some of the targeted DCIs.	**Purposeful DCIs.** All targeted DCIs are necessary for sense-making and problem solving.
Applying science. Engineering lessons only apply science ideas from physical, life, or Earth and space sciences students have already developed.	**Developing science.** Engineering lessons require students to acquire new understanding of physical, life, or Earth and space sciences to solve design problems.
No DCIs needed. Engineering lessons focus on trial-and-error activities or following step-by-step instructions that require neither science nor engineering knowledge.	**Both science and engineering DCIs needed.** Students use grade-appropriate science ideas (DCIs from life, Earth, or physical sciences) together with elements of DCIs from engineering design (ETS) to solve design problems.

The phenomena and problems driving learning need to closely match the learning goals. High-quality materials both: 1) maintain student engagement throughout learning through a continued focus on phenomena and problems, and 2) give students opportunities to reach all learning goals. This means:

- The sense-making and problem solving is contextualized and facilitated for students such that most student questions can be answered using the targeted learning goals, and
- All learning goals are necessary to learn in order to explain the phenomenon or solve the problem (to a grade-appropriate level).

When learning goals closely match driving phenomena and problems, the entire learning sequence becomes more engaging and authentic to students. No part of the learning seems like an isolated add-on.

As an illustration, the phenomenon of a stick appearing to break when it enters water requires middle school students to learn MS.PS4.B DCI elements about electromagnetic radiation in order to explain it. After understanding these concepts, the entire phenomenon can be explained to a level that will be satisfactory to middle school students. However, this phenomenon would not be sufficient if students also needed to learn MS.PS4.C ideas about digitized signals — there would no longer be a close match between the phenomenon and the learning goals.

This attention to matching is particularly important for DCI-related learning goals, as SEPs and CCCs can more easily be used to explain or solve a wider range of phenomena and problems and are intended to be used repeatedly throughout instruction in many combinations. In contrast, in most instructional programs, students only encounter each DCI element one time.

Same phenomena for different grade bands. At times, the same phenomenon may be appropriate for multiple grade levels, with the area of focus or complexity of explanation increasing by grade level. For instance, a pattern of similar appearance between parents and offspring can lead young students to learn that "young animals are very much, but not exactly like, their parents" — a DCI for first grade, whereas it can lead older students to learn about genetic traits and mutations — a DCI for middle school. The difference is in the prior knowledge students bring to class, the grade-appropriate learning goals, the way the phenomenon or problem is contextualized for students, and in the facilitation the teacher provides during instruction.

Common challenges. Currently, many instructional materials reviewed have fairly close alignment between the learning goals and what figuring out the phenomenon or solving the problem would require the students to learn. In some cases, however, either the phenomena or problems are framed such that grade-inappropriate science ideas would be needed to explain them, or only some of the DCI learning goals would be needed to explain them and the other targeted DCIs would be learned before or after the sense-making process.

> "When learning goals closely match driving phenomena and problems, the entire learning sequence becomes more engaging and authentic to students. No part of the learning seems like an isolated add-on.

Another common issue is limiting sense-making or problem solving to the end of instruction, as a way for students to demonstrate they can apply ideas they've learned. This is seen particularly often with engineering-related activities. Materials do not often ensure that science DCI *development* continues while students solve problems. In high-quality materials, student learning continues throughout an instructional unit and students learn both science and engineering ideas in order to solve problems, as illustrated in "Unit B" in Critical Feature 2.1 (page 18).

Critical Feature 2.3: Integrating Learning of the Three Dimensions

THREE-DIMENSIONAL LEARNING IS	
LESS LIKE...	**MORE LIKE...**
DCIs only. Materials focus only on developing students' DCI understand ing, or only DCI understanding is included in a grade-appropriate way.	**All three dimensions.** Materials help students build proficien-cy in grade-appropriate elements of all three dimensions.
Dimensions one at a time. Students learn the three dimensions in isolation from each other (e.g., a sepa rate lesson or activity on science meth ods or skills followed by a later lesson on science knowledge, front-loading DCI acquisition followed by applica tion with SEPs and CCCs, etc.).	**Integrated learning.** Students learn elements from multiple dimensions in tandem, such as using partial understanding of an SEP or CCC element to help begin developing understanding of a DCI element, and along the way developing more knowledge about and proficiency with the SEP and CCC elements.
Ambiguous language. Student-fac ing materials use inaccurate or confus ing language, such as not distinguishing between the common English meaning of "argument" and the scientific practice of argumentation.	**Clear language.** Student-facing materials have precise, grade-appropriate wording to help students scaffold their under-standing of concepts in all three dimensions to avoid creating misconceptions.

"In addition to setting integrated three-dimensional learning goals, high-quality materials also integrate the three dimensions in student experiences throughout the learning process.

Section 1 of this resource discussed critical features related to learning goals, including for all three dimensions of the standards (SEPs, CCCs, and DCIs) and their use together. In addition to setting integrated three-dimensional learning goals, high-quality materials also integrate the three dimensions in student experiences throughout the learning process. This approach to learning closely reflects the work of practicing scientists and engineers. It also helps students more deeply understand SEPs and CCCs and their utility — by using them in many different contexts.

Grade-appropriate two- or three-dimensional goals. Multidimensionality is one clear area where materials have improved over time, as very few reviewed materials now include significant amounts of any one-dimensional learning. However, although materials show more evidence of two- or three-dimensional activities, the second or third dimension is frequently designed at the level of the prior grade band. For instance, middle school materials sometimes focus on initial student development of an elementary-level SEP element together with grade-appropriate DCI development. To ensure that students have opportunities to fully develop all three dimensions, it is important that learning goals use grade appropriate elements for each of the three dimensions that are targeted, not just DCIs. See NGSS Appendices E, F, and G for descriptions and matrices of the grade band progressions in each dimension.

Accuracy. In addition to being grade appropriate, each dimension is also scientifically accurate in high-quality materials. Most materials reviewed by EdReports and Next-GenScience are accurate overall with only minor wording issues that might lead to misconceptions in any one of the three dimensions (e.g., thinking that experimental results can "prove" a theory, representing guesses as hypotheses, or conflating causation and correlation). However, some materials still isolate teaching of the scientific method or engineering design process, resulting in rote one-dimensional learning and potentially inaccurate perceptions of how science and engineering work in the real world. When materials portray accurate, three-dimensional learning, they remove the need for teachers to create additional activities or lessons to address student misconceptions that were inadvertently introduced.

The following vignette illustrates this critical feature, showing students integrating all three dimensions in order to make sense of a phenomenon.

> *A group of high school students is working toward explaining the phenomenon that only one kind of plant in a field survived a drought. After they plan and conduct an investigation to examine the responses of different plant parts to stimuli, they are asked to reflect on what didn't work well in their investigation setup. They discuss with a partner ways to change the experimental design this time, and compare their measurements taken with a digital thermometer (that measures to a tenth of a degree) to those taken with an analog thermometer (with tick marks for every two degrees). One team of students notices that they can see a new pattern in their data from the digital thermometer. The teacher facilitates a class discussion using examples from students' prior science units to come to the conclusion that patterns observable at one scale (such as the smaller scale measured by the digital thermometer) may not be observable at other scales [a CCC]. Students then apply this understanding to determine appropriate tools to collect data for their experiment [an SEP]. Using this new understanding, students revise their experimental design to get more precise data, allowing them to make a claim about how stomata respond to temperature changes, building toward an understanding of feedback mechanisms [a DCI].*

> **"When materials portray accurate, three-dimensional learning, they remove the need for teachers to create additional activities or lessons to address student misconceptions that were inadvertently introduced.**

Critical Feature 2.4: Supporting students to use all three dimensions in an integrated way to sense-make or problem solve

INTEGRATING THE DIMENSIONS FOR SENSE-MAKING AND PROBLEM SOLVING IS	
LESS LIKE...	**MORE LIKE...**
Learning is only *related* to phenomena. The expected learning in the three dimensions is only loose ly connected to the phenomenon or problem.	**Learning *explains* phenomena.** The three dimensions work together to help students explain a phenomenon and/or design solutions to a problem.
Learning is separate from sense-making. Students see their three-dimensional learning as sep arate from their sense-making or problem solving.	**Learning is through sense-making.** Students see how their learning for each targeted learning goal works in service of sense-making and/or problem solving.
One or more dimensions is unnecessary. Students would be able to explain the phenomenon without using or developing one of the dimensions (often CCCs).	**All three dimensions are necessary.** All three dimensions are necessary for sense-making and problem solving.
Implicit or absent CCCs. Materials don't make CCCs explicit to students. For instance, students write an expla nation about a phenomenon but aren't asked to include information about how causal relationships relate to their explanation.	**Explicit use of CCCs to sense-make.** Materials require students to explicitly use the CCC elements to make sense of a phenomenon and/or to solve a problem. For instance, the materials prompt students to discuss a causal relationship as part of their explanation about a phenomenon.
Implicit or absent cross-disciplinary connections. CCC use across science domains, such as how systems interact in both physical sciences and life sciences, is not explicitly pointed out to students.	**CCCs explicitly connect across disciplines.** The way the same element of a CCC can be used together with different science domains to make sense of different phenomena is made clear to students.

> High-quality materials ensure that students not only learn three-dimensionally but do so in a way that all three of the dimensions work together to help students explain a phenomenon or design solutions to a problem.

Having students integrate the three-dimensions with a scope that closely matches what is required to explain the driving phenomena and problems is necessary but not sufficient. Students also need to use those three dimensions throughout instructional activities for the *purpose* of explaining a phenomenon or designing solutions to a problem. High-quality materials ensure that students not only learn three-dimensionally but do so in a way that all three of the dimensions work together to help students explain a phenomenon or design solutions to a problem. Each of the three dimensions is necessary for the sense-making or problem solving; if any one of the three were missing, students wouldn't be able to fully explain the phenomenon or solve the problem.

Metacognition. The goal of learning goes beyond student performance in the classroom. Students need opportunities to build proficiencies that will serve as tools to help them solve problems in the real world and make sense of phenomena in everyday life. These tools are most effective when students know about them explicitly. Therefore, one goal of high-quality materials is to help students build an explicit understanding of what they are learning and how it can be applied in other situations. This doesn't mean that students need to memorize the three dimensions, but that they are familiar enough with the different cognitive tools they are using so they can remember to apply them again in the future.

Metacognitive prompts can help students retain information better and can make learning more purposeful by helping students understand why they are learning. High-quality materials support teachers by providing facilitation guidance to help students see connections between each of the three dimensions and the phenomenon or problem. However, in many reviewed materials, this kind of teacher support is missing. Teachers *themselves* are often supported in front matter or overview materials to see why and how all three dimensions are necessary to explain the phenomenon or solve the problem, but students are not often given this guidance or opportunity for reflection, and teachers are not prompted to help students see these connections.

> High-quality materials support teachers by providing facilitation guidance to help students see connections between each of the three dimensions and the phenomenon or problem.

Crosscutting Concepts. Currently, only about half of reviewed materials support students to engage in performances that require grade-appropriate elements of all three dimensions working together in service of sense-making or problem solving. Often when this does not happen, it is because students are not supported to use grade-appropriate CCCs to make sense of something. Even when CCCs are used, they are typically only discussed in reference to the single science domain under investigation rather than being discussed as a tool that was helpful in another context and that might be applied to a new context. High-quality materials take advantage of the power of the CCCs, which is to have a broadly applicable mental tool that can be applied in the future to figure out phenomena or solve problems across science and engineering domains.

> **Only about half of reviewed materials support students to engage in performances that require grade-appropriate elements of all three dimensions working together in service of sense-making or problem solving.**

When used together explicitly, the three dimensions can be powerful tools for student sense-making and problem solving. The following vignette illustrates this critical feature.

> *Students have been working toward explaining the phenomenon of a tree gaining mass. They are prompted to think about the different CCCs they have used before and consider which one they want to use to help them start figuring out the phenomenon. When students talk about systems, they are facilitated to use the CCC element "systems may interact with other systems; they may have sub-systems and be a part of larger complex systems" to consider whether a tree interacts with a larger system, and if so, what the components of that system are. They also consider what sub-systems might operate within a tree. As students progress in their sense-making, the teacher calls out the different ideas and SEPs students use and asks students what role those components are playing in helping them figure out the phenomenon.*

Note that in this illustration, while the students are supported to feel as if they are driving instruction through careful teacher facilitation, the materials provided guidance to ensure that students were supported to use a specific CCC element. The materials did not leave this to chance or only expect that students who could think of this connection on their own would use the CCC element.

Critical Feature 2.5: Supporting students to feel as if they are driving the learning

STUDENT-DRIVEN LEARNING IS	
LESS LIKE...	MORE LIKE...
Teacher-led. Students have the impression that the decision of what to do next in instruction rests solely with the teacher.	**Student-led.** Students have frequent opportunities to feel as if they are driving the learning sequence through their questions and emerging understanding.
Materials or the teacher provide driving questions to students. Driving questions to investigate throughout the learning experience are given to students.	**Students develop driving questions.** Materials support teachers to facilitate discussions such that student questions, prior experiences, and diverse backgrounds related to the phenomenon and/or problem can be used to drive the learning from the students' perspectives.
Learning is disconnected from student questions. Even when student questions are elicited, they are not the focus of learning. Instead, the lesson tells the students the science they will be learning. For instance: "To day we're going to learn about cells."	**Learning focuses on answering student questions.** The lesson provides support to teachers and students for connecting students' own questions to the targeted materials. For instance: "Today we decided that we're going to try to answer the question we had yesterday about what those things were that we saw in the microscope to try to figure out what might be going on in the water."
Student questions are not revisited. Questions that arise from one investigation are not revisited or are only revisited at the end of the unit. There is no teacher guidance to connect these questions to future lessons and these questions are never revisited.	**Student questions are revisited and create coherence across activities.** Teachers are given facilitation prompts to help students develop curiosity about the learning that is planned for future lessons and ask questions that are then answered in subsequent lessons. Materials support teacher navigation of unanswered student questions.

Phenomena and problems are not intended to drive learning alone; they are intended to motivate students, sparking a desire to figure something out or find a solution. It is therefore student questions *about* the phenomena and problems that are intended to drive learning. Teachers no longer need to fill the role of content providers — they instead are facilitators to help move students down a learning path that will productively help them: 1) figure out a phenomenon and/or solve a problem, and 2) reach or exceed the targeted learning goals for all three dimensions.

> **Fewer than half of reviewed materials currently show evidence that students are facilitated to feel that their curiosity or questions about phenomena and/or problems, or their ideas related to prior experiences, are directing the learning sequence.**

Although this is one of the most important critical features of high-quality materials, this is one of the rarest features to find. Fewer than half of reviewed materials currently show evidence that students are facilitated to feel that their curiosity or questions about phenomena and/or problems, or their ideas related to prior experiences, are directing the learning sequence.

Guidance for teacher facilitation. Supporting teachers to facilitate student questioning and thinking is a large part of high-quality materials, and it can be difficult to strike the balance between leading too much and too little. When students feel as if their questions are critical in decisions about what to do in the next instructional activity, student agency and ownership over the learning increases, improving student participation and engagement.

Multiple approaches to teacher facilitation can ensure students feel as if they are driving the learning. For instance, below are two of many possible approaches to facilitate student thinking after the introduction of a phenomenon.

Learning Sequence A: Building a Driving Question Board

- Students generate questions about a phenomenon, and the teacher asks the class to share questions and group similar questions together on a driving question board. During this process, the teacher asks guiding questions that prompt students to choose groupings that correspond with sense-making steps the teacher knows need to happen.
- The teacher lets the class know that they will have the opportunity to address all of those groupings, and that they just need to decide which one to address first.
- The teacher then facilitates a class discussion to make this decision, asking guiding questions that help the class realize which questions need to be answered first before other investigations could be fully planned. The teacher paraphrases and connects student ideas for how to begin answering that first group of questions.
- The next lesson begins by reminding the class what they decided to investigate first, and then proceeding with that investigation. As the class addresses each question grouping, this navigation routine is repeated until all closely relevant student questions are answered, with other less-related questions being encouraged for enrichment or independent study.

Learning Sequence B: Filling in Gaps in Student Models

- Students develop a model of what they think is going on in the phenomenon. In pairs, students discuss and compare models and then contribute ideas to develop a class consensus model.
- The teacher prompts students to identify which parts of the consensus model they need more information to understand. Students are then asked to generate testable questions about each part of the model that is not yet clear.
- The teacher facilitates a discussion to help students determine which part of the model should be investigated first and how this should be done, building from student ideas that are most relevant to the sense-making.
- The next lesson begins by reminding the class what they decided to investigate first, and then proceeding with that investigation. As the class figures out the answer to their questions about each part of the model, this navigation routine is repeated.

High-quality materials provide teachers with guidance to support the kind of teacher facilitation seen in both Learning Sequences A and B. In both cases, a key feature is the *frequent explicit reminder to students that what they are doing in class is in response to their questions.* The teacher helps students link each new step to their own questions and ideas. In addition, in both learning sequence illustrations, students and teachers are the co-creators of the driving questions. Students were not left on their own to go in any direction they wanted — they were carefully guided to be genuinely curious about going down a productive, coherent path.

Critical Feature 2.6: Sequencing lessons and units coherently and linking them together logically from the students' perspectives

COHERENT LEARNING PROGRESSIONS ARE	
LESS LIKE...	**MORE LIKE...**
Teacher-focused coherence. Lessons fit together in ways that are only apparent to the teacher.	**Student-focused coherence.** Lessons are sequenced logically in a way that is coherent from the students' perspectives. Students can see how what they are trying to figure out or solve in one lesson builds on previous lessons and fits into the goals for the sense-making or problem solving.
Sequencing logic communicated only to teachers. Only teachers are supported to see how lessons fit together.	**Sequencing logic communicated to students.** Teachers are supported to help students see how lessons fit together.
Disconnected lessons. A different, unrelated phenomenon or problem is used to start every lesson.	**Connected lessons.** If multiple phenomena and/or problems are used, they are explicitly connected and build on each other.

"When students see and understand the connection from point A to point B throughout instruction, they feel as if their learning is coherent.

To further help strengthen students' agency and feelings that their questions are driving learning, each step in the learning process needs to flow logically from the perspective of the students. When students see and understand the connection from point A to point B throughout instruction, they feel as if their learning is coherent.

If student questions about phenomena and/or problems are used to drive learning as described in the previous critical feature, coherence in learning will come naturally. However, student questions are not the only way to increase coherence. The focus for this critical feature is on materials helping students see the logical flow and connections throughout learning, whether those connections come from students' own questions being answered or not.

Starting with relatable and concrete ideas. In materials reviewed by EdReports and NextGenScience, most lessons are linked topically and content is sequenced logically from the teacher's perspective. However, many of these materials don't show evidence that students themselves would clearly see how lessons flow into one another. What makes sense as a connection to an adult may not necessarily be as clear to a student. The National Academies of Sciences, Engineering, and Medicine report [*Investigation and Design at the Center*]() illustrates this point, referring to the common practice of biology classes to teach cell structure first, followed by cell function, missing an opportunity to ensure coherence for the students by starting with more relatable and concrete ideas.

"From a student's perspective, until the class has established that cells need to take in food and get rid of waste, and that these molecules need to cross the cell membrane to do that, there is no motivation to figure out how materials enter and exit cells. Establishing that cells need to obtain energy then raises the question about what could get into or out of a cell and motivates investigating what can get through a membrane."

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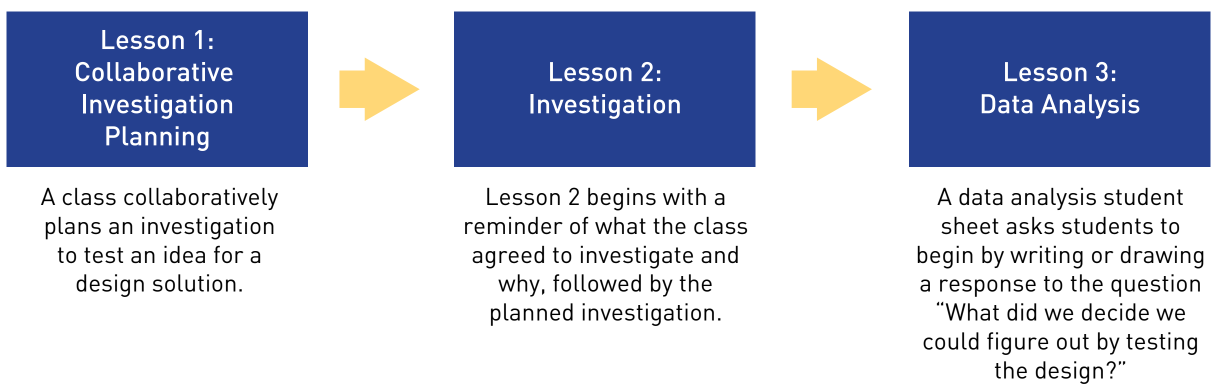
Reminders of coherence throughout. Coherent connections are important for students to see not only on the front end — when going from point A to point B — but also on the back end. When students are at point B, it is often helpful to remind them why they're at point B and how they got there from point A. For instance:



In this illustration, students were able to clearly see the connection between the lessons because they participated in Lesson 1 in planning the actual activities used in Lesson 2. They also were reminded twice of what they decided in Lesson 1, ensuring that all new learning would be contextualized and meaningful.

Critical Feature 2.7: Engaging students with relevant and meaningful phenomena, problems, and activities

RELEVANT, AUTHENTIC, AND ENGAGING PHENOMENA, PROBLEMS, AND ACTIVITIES ARE	
LESS LIKE...	**MORE LIKE...**
Students hear or read about phenomena and problems. For instance, teachers tell students about a phenomenon or problem in the world.	**Students experience phenomena and problems as directly as possible.** Students directly experience, preferably firsthand or through media representations, a phenomenon or problem.
Assumed student interest. The materials assume the phenomena and problems will be interesting to all students.	**Evidence of student interest.** The materials are developed based on data from diverse student groups to determine interest and potential for engagement for wide audiences.
Unclear real-world relevance. The phenomena or problems don't seem to be connected to the real world. For instance, students might think a classroom demonstration of a collapsing coke can is interesting, but might not think it is relevant to the real world until they see a collapsing tanker.	**Relevance to students is clear.** The phenomena and problems are authentic and meaningful to a range of student backgrounds and interests. Students can clearly see how the phenomena and problems are relevant to them or to others they can relate to. Therefore, they also see why the science and engineering necessary to explain the phenomenon or solve the problem is relevant and important to learn.
Narrow relevance. The materials focus on examples that only some of the students in the class understand.	**Inclusive contexts.** Materials use examples that are accessible to all students and provide support to teachers for ensuring that students fully understand all examples and contexts.

"

It is essential to not only match phenomena and problems to three-dimensional learning goals, but also to the interests and frames of reference of the participating students.

Not all phenomena and problems will compel and motivate students enough to generate questions or interest in learning. It is therefore essential to not only match phenomena and problems to three-dimensional learning goals, but also to the interests and frames of reference of the participating students. This is also true of each learning activity in which students engage.

Students' prior knowledge and experiences. Students are the center of instruction, so instructional design needs to focus on students' unique prior knowledge, interests, and perspectives. Phenomena, problems, and activities that are engaging to some students may not be motivating to other students. High-quality materials therefore, not only use driving phenomena, problems, and activities that are free from bias and widely engaging to students of the targeted age, but also provide guidance to teachers for tailoring instructional features to their own students and contexts, such as suggesting alternate investigative phenomena, local data sets, or considerations for coherence when modifications are made. This kind of thoughtful planning ensures that all students are engaged in learning that seems relevant and useful to them and to their communities.

Relevant engineering problems. Most of the instructional materials reviewed by EdReports and NextGenScience show some evidence that students would find driving phenomena and activities engaging and relatable. However, when engineering problems are used to drive instruction, fewer supports are typically provided to help all students understand the relevance and importance of solving the problem. Instead, students are often asked to solve the problem simply because the teacher said so.

An illustration of engaging students in relevant and meaningful learning through problem solving is described by the following learning sequence from the Girls and the Next Generation Science Standards case study from Appendix D of the NGSS.

> *"Students go into a nearby forest to observe and count the types of shelter and food sources available for animals there. They then gather information about the food available at different times of the year and identify the problem that some animals don't have enough to eat during certain months. The class decides to identify plants that would help address the problem, and then plants them in the forest."*

Local Relevance. The experience described above is engaging for young students because it ties directly to their local community, and they directly observe the context and collect the data themselves that led to recognizing the problem. Note that older students don't need problems and phenomena to be localized as often as is necessary for very young students. It is especially important for high school students to be supported to see the relevance in problems at a regional, national, and even global scale.

Critical Feature 2.8: Supporting teachers to connect student assets and culture to instruction

CONNECTING TO STUDENTS' CULTURE AND BACKGROUND IS	
LESS LIKE...	**MORE LIKE...**
Content delivery focus. Teacher materials focus on disciplinary content delivery without providing support to help teachers understand, value, and build on the experiences and knowledge that students bring to the classroom.	**Student culture focus.** Teacher materials focus on connecting instruction to the students' homes, neighborhoods, communities, and cultures as appropriate, and provide multiple opportunities for students to support their learning with questions and ideas from their own funds of knowledge.
One classroom discourse strategy. Materials support and promote only one style of discourse (e.g., full class oral discussion) or fail to clearly describe inclusive strategies for discourse. As a result, only some students feel comfortable sharing their ideas.	**Varied classroom discourse strategies.** Teacher materials provide guidance to help all students make productive contributions to classroom discourse in a variety of ways.
Few ways to learn. Materials pro vide few options for meeting learning goals, such as reading about topics, listening to lectures and note-taking, and following written directions to complete labs.	**Multiple ways to learn.** Materials provide multiple access points and modalities for students to learn. For instance, students can construct understanding through use of the SEPs using various modalities, including reading both text and diagrams; writing, drawing, and gesturing to develop models; and speaking and listening through argumentation and evidence-based discourse. Materials also provide support for all students to make thinking visible in ways that are less dependent on English language proficiency.

"

When teachers help students use their different assets during the learning process, students can learn more and can increase their feeling of connection and engagement with science and engineering.

Students are the most important part of the education system and each student is unique. They all enter class with different talents, prior knowledge, understanding, backgrounds, and families that shape their current experience and identity. These experiences can be assets for navigating the natural and designed world. When teachers help students use these different assets during the learning process, students can learn more and can increase their feeling of connection and engagement with science and engineering.

Leveraging assets. Building on students' assets is an area that needs improvement in the instructional materials field. A majority of reviewed materials help students make some connections between the classroom activities and their home lives, although these connections are rarely leveraged to motivate learning. Very few materials provide support to teachers to help engage students' curiosity in a way that pulls from and connects to their funds of knowledge.

> "Funds of knowledge…are the valuable understandings, skills, and tools that students maintain as a part of their identity. Families have funds of knowledge from aspects of everyday life, such as fixing cars, working in a business, or building homes.
>
> *How People Learn II: Learners, Contexts, and Cultures (2018)*

Community connections. Materials that make connections to students' communities and funds of knowledge can increase student and family engagement by providing a valuable and meaningful starting point for learning. As an illustration, when students are considering an anchor problem to solve in an instructional sequence, they may be asked to think about similar situations that they or their family members have experienced. They could interview their family or community members to learn about similar situations and how they were addressed, and then bring that knowledge back to class as possible starting points for how the class problem might be addressed.

Varied ways to demonstrate understanding. Materials that give students the flexibility to engage through different modalities (e.g., written, oral, drawing, gestures) not only support student learning and accurate portrayal of student ideas during assessment, but also allow students to feel they're being heard and respected by their teacher and peers. An increasing number of materials center student discourse in learning activities and ensure that students have opportunities to engage through multiple modalities during instruction. However, these design approaches are less common in reviewed unit and program assessments. In addition, few reviewed materials currently support teachers to value, rather than simply accommodate, non-dominant modes of communication, such as those described below.

There are many ways materials can help ensure that all students, including emerging multilingual learners, feel valued and engaged throughout the learning process. For instance, during class discourse, materials could design learning activities or provide teacher facilitation guidance for students to:

- work in small groups to share initial ideas before sharing with the class,
- express their initial ideas in their home language, and
- choose whether to share their ideas in writing, orally, or through pictures and storyboarding. In this last case, high-quality materials also provide teachers with modality-independent scoring guidance or student "look-fors."

Section III: Student Assessments

> **How school systems evaluate the learning derived from educational standards — through high-stakes tests, formative classroom assessments, and informal evaluations of learning during instruction — has a driving influence on educational pathways and equity.**
>
> *A Framework for K–12 Science Education*

Today's science standards, such as the NGSS, are built as performance expectations to detail what students should be able to perform at the end of instruction. It may take an entire school year or even multiple years to build towards these learning goals.

The assessment system in high-quality materials provides a mechanism for students and teachers to understand and support student progress towards those performance expectations. Although the assessments within that system differ in form and function, they provide frequent formative and summative opportunities to monitor student progress toward the learning goals, enabling modifications to instruction along the way as necessary.

Features of high-quality assessments mirror many of the expectations for high-quality instruction described in Sections 1 and 2 of this document. Assessment systems support high-quality instruction when the different system components work together to create meaningful, empowering, accessible, and fair opportunities for all students — particularly those historically underserved in the science classroom — to be able to show what they know and can do. These aspects are intertwined with other critical features in this document to allow teachers to better support all students to make progress toward their learning goals.

High-quality materials designed for today's science standards include the four critical features on the next page related to student assessments.

STUDENT ASSESSMENTS CRITICAL FEATURES

Critical Feature 3.1: Requiring use of multiple dimensions. Materials include opportunities for students to engage in meaningful assessment tasks, many of which require the use of all three dimensions together to make sense of phenomena or design solutions to problems. Students also have opportunities to transfer knowledge and practice across contexts.

Critical Feature 3.2: Supporting students with accessible and coherent assessments. Tasks empower and build student confidence by including multiple ways for students to both access the task prompts and to make their thinking visible. They have appropriate scaffolds and accessible language, and flow in a way that is understandable from the student perspective such that they are motivated to complete the task.

Critical Feature 3.3: Including scoring guidance and supporting teachers to provide feedback related to student use of the three dimensions. Materials include task-specific scoring for the relevant grade-appropriate learning goals (i.e., the "element level" of each of the three dimensions — see glossary), guidance for teachers to adjust instruction based on student responses, and opportunities for students to obtain and reflect on feedback from teachers and peers.

Critical Feature 3.4: Designing a coherent assessment system. A coherent assessment system includes alignment between goals of assessments and learning, an understanding of how students progress towards the grade or grade-band performance expectations, and teacher guidance to use various components of the system coherently to support student progress.

Critical Feature 3.1: Requiring use of multiple dimensions

MULTI-DIMENSIONAL ASSESSMENTS ARE	
LESS LIKE...	MORE LIKE...
One dimension. Students only need to use one dimension to successfully complete the task. This can happen when prompts focus on science topics rather than making sense of phenome na or solving problems.	**All three dimensions.** Successful performance on assess-ments requires use of all three dimensions within the full set of questions in a task.
Dimensions assessed in isolation. Tasks only assess DCIs, CCCs, and SEPs in separate prompts.	**Integrating dimensions.** Most questions require students to use at least two dimensions together. Not every prompt within a high-quality task needs to be three-dimensional.
One question type. Long assess ments use a single modality or design when assessing each dimension (e.g., solely using multiple choice questions to assess DCI knowledge).	**Varied question types.** Long assessments incorporate tasks with multiple components (i.e., composed of more than one kind of activity or question) that allow students to demonstrate their knowledge and ability to use grade-appropriate elements of multiple dimensions together.
Phenomena already explained. Assessments ask students to explain the same phenomenon they already worked to explain during instruction, thus only testing one-dimensional rote knowledge.	**Applying learning goals to new phenomena or problems.** Assessments ask students to transfer their ability to figure out phenomena or solve problems in new contexts through the application and use of all three dimensions present in the learning goals.
Decreased rigor. Assessments are at a lower rigor or grade-level than instruction.	**Grade appropriate.** Assessment targets are grade appropri-ate and give students an opportunity to demonstrate the learning goals developed during instruction.

> **Although understanding the language and terminology of science is fundamental and factual knowledge is very important, tasks that demand only declarative knowledge about practices or isolated facts would be insufficient to measure performance expectations in the NGSS.**
>
> *Developing Assessments for the NGSS*

High-quality assessments allow students to demonstrate that they can use practices, core ideas, and crosscutting concepts together to make sense of a phenomenon or solve a problem. These opportunities may look different across high-quality materials, but are structured in a way that builds towards students demonstrating their ability to transfer understanding of the targeted three dimensions in novel contexts, such as with a new phenomenon or problem to address.

Integration of the three dimensions at a grade-appropriate level. In many instances, the assessment component in materials reviewed by EdReports and NextGenScience only assess single dimensions in isolation, which does not provide students the ability to demonstrate how they can authentically engage in science or engineering.

> **Larger assessment systems in high-quality materials ensure a comprehensive opportunity for students to demonstrate all grade-level or grade-band outcomes by the end of the grade or course.**

In instances where multiple dimensions are assessed, curriculum reviewers often find that they are not at a grade-appropriate level, most often below the targeted grade level or band. It is essential that assessments allow students to demonstrate their understanding and use of multiple grade-appropriate dimensions. Larger assessment systems in high-quality materials ensure a comprehensive opportunity for students to demonstrate all grade-level or grade-band outcomes by the end of the grade or course.

Phenomena or problem-based contexts. To help ensure that students can demonstrate their learning in an equitable manner, assessment tasks need to make sense to the students so that they can test, apply, and transfer (in longer tasks) the targeted three-dimensional knowledge and abilities. Summative assessment tasks in high-quality materials provide new contexts through a novel phenomenon or problem, allowing students to step into a new scenario and be motivated to demonstrate their learning. The new scenario can be presented in a variety of ways, but is ideally similar in structure to the phenomena and problems used in the learning opportunities, allowing for congruence between students' learning and practice with the three dimensions and the assessment.

Common challenges. The inclusion of phenomena or problems does not guarantee that students have opportunities to transfer their three-dimensional knowledge and skills. There are two common scenarios when this may be the case, each paired with a solution.

- ***Phenomena already explained.*** Phenomena or problems are used in assessment, but they are the same phenomenon or problem from instruction. When the same phenomenon is used from instruction, students may be able to merely repeat the explanation discussed during instruction, and therefore not demonstrate their proficiency in making sense of the phenomenon using the three dimensions. This reduces the opportunity to make successful claims from student performance. Conversely, when the knowledge and practice developed during instruction are required to explain a *new* phenomenon or solve a *new* problem, students have the opportunity to use multiple dimensions to show what they know and can do.
- ***Phenomena as hooks.*** A phenomenon or problem is included to introduce the task, but the prompts ask students about general science topics *connected* to the phenomenon rather than to explain the phenomenon itself. Instead, high-quality tasks prompt students to use multiple dimensions together to explain the phenomenon or design a solution to a problem.

Applying learning goals to new phenomena or problems. High-quality materials provide opportunities for students to demonstrate proficiency in the same dimensions used and developed during instruction, but in a new context. There are many ways to do this. Below is an illustration of one approach.

> *Students have learning goals that include constructing arguments [SEP]; some cause-and-effect relationships can only be described using probability [CCC], and MS.LS3.B about chromosomal contributions from each parent [DCI]. During instruction, the class focuses on trying to figure out the phenomenon of red and green appearing identical to some boys. Formative assessments ask students to construct and present an oral or written argument supported by empirical evidence and scientific reasoning to support the claim that being male doesn't cause color blindness, but there is a probabilistic cause-and-effect relationship. A summative assessment then asks students to transfer their learning to construct an oral or written argument supported by empirical evidence and scientific reasoning that describes the cause-and-effect relationship between being male and balding.*

Critical Feature 3.2: Supporting students with accessible and coherent assessments

ACCESSIBLE AND COHERENT ASSESSMENTS ARE	
LESS LIKE...	**MORE LIKE...**
Focus on right and wrong answers. Assessments only prompt student artifacts that show answers without describing reasoning. Students are unable to show partial proficiency in the learning goals.	**Focus on student reasoning.** Assessments prompt student artifacts that show detailed descriptions of reasoning behind their answers in written, oral, pictorial, and/or kinesthetic forms. Students are able to share what they know and can do even if they don't have full proficiency in the learning goals.
One way for students to show thinking. All students are required to demonstrate their thinking in the same way (e.g., writing, academic English) limiting the opportunity for some students to fully demonstrate their understanding.	**Multiple ways for students to show thinking.** Students are offered a choice of modality (e.g., "write or draw your ideas") to express their thinking, ensuring all learners have the opportunity to demonstrate their progress.
Prompts given in one modality. Materials only communicate student assessment expectations in one way. For instance, teachers are prompted to orally tell students what to do, and student-facing materials do not communicate expectations in other modalities.	**Prompts given in multiple modalities.** Materials communicate student assessment expectations in a variety of ways to ensure all students understand exactly what the task is asking them to do.
Inaccessible. Contexts or content in task scenarios are unfamiliar or in accessible to some students. The task requires the students to know things outside the expected learning expe riences, preventing all students from being able to engage fully in the task.	**Accessible.** Materials provide guidance for teachers to ensure each student can fully understand and access task scenarios, and task scenarios make connections to student background knowledge and interests to make the task more meaningful and motivating for students. Knowledge outside the expected learning experiences is not required to successfully complete the task.

Critical Feature 3.2: Supporting students with accessible and coherent assessments (continued)

ACCESSIBLE AND COHERENT ASSESSMENTS ARE	
LESS LIKE...	MORE LIKE...
Disconnected. Students don't know why they're engaging in parts of a task, or task prompts appear to be unrelated to the learning experience from the students' perspectives.	**Coherent.** Tasks have a logical order. Within a task, each prompt is connected and relevant to the overall sense-making or problem solving so students know why they're doing what they're doing in each part of the task.

> "The overall goal of assessment is for both teachers and students to understand students' thinking, understanding, and proficiencies. The only way to do that is to ensure that assessments are equitable and accurately measure the performance of each student.

The overall goal of assessment is for both teachers and students to understand students' thinking, understanding, and proficiencies. The only way to do that is to ensure that assessments are equitable and accurately measure the performance of each student. When this goal is reached, teachers get clear information about every student's progress and can support their learning much more effectively than if assessments only made sense to some students, or only measured dominant ways of expression.

Empowering assessments. When assessment tasks allow students to share reasoning behind their answers rather than solely right or wrong answers, teachers are better able to learn what students know and can do. This gives students the ability to engage with the task in a robust way even when their understanding isn't fully developed. Allowing students to share reasoning also gives them choice (e.g., which evidence to use, how to address a phenomenon) that can increase feelings of ownership and agency.

Multiple modalities. Currently, most instructional materials reviewed by EdReports and NextGenScience prompt students to generate artifacts in multiple modalities, making thinking visible in different ways. For instance, students are often asked to describe their reasoning through both linguistic (e.g., writing and oral discussions) and non-linguistic (e.g., drawing, gestures, charts, simulations) modalities over the course of an instructional unit. This allows a more complete picture of student progress, ensuring that all students have opportunities to demonstrate their proficiency without being constrained to only one modality or to only single word "correct" answers.

> **High-quality instructional materials prompt teachers to give students choices of which modalities to use to show their thinking during assessments.**

High-quality instructional materials go even further, prompting teachers to give students choices of which modalities to use to show their thinking during assessments. Having autonomy to choose and the opportunity to express themselves in their strongest modality can allow students to build confidence in their science abilities. However, very few reviewed materials currently provide students with this kind of choice.

Accessible prompts. An important step to making assessments equitable is to ensure that assessment prompts are accessible to all students. As with student response options, assessment prompts themselves can be provided in multiple modalities and multiple languages, such as with a teacher's oral description or diagramming of a task accompanying written prompts in students' own home languages. This is currently an area of strength in reviewed materials. Many use grade-appropriate vocabulary and text volume, and communicate student expectations in multiple ways, such as by prompting teachers to orally convey instructions in addition to providing written instructions for students.

Item prompts in high-quality materials also follow principles of Universal Design for Learning and are written with clear and simple language rather than complex grammatical structures. These design considerations help ensure that students are assessed on their science proficiency rather than advanced reading comprehension. Similarly, materials thoroughly communicate any vocabulary terms used in assessments (i.e., as part of a transfer task) that weren't already used in instruction to ensure all students can understand what is being asked.

Accessible scenarios. In addition to understanding assessment prompts, students also need to understand the task contexts or scenarios. In high-quality instructional materials, task scenarios are free from bias and are either:

- based on problems or phenomena that all students would already be familiar with, such as dying plants or sunsets, or
- accompanied by images, videos, demonstrations, or hands-on experiences to ensure students have a common understanding of, and entry point to, the scenario.

Building student familiarity with the task scenarios helps to ensure that successful completion of a task won't require knowledge outside the expected learning experiences.

Ideally, task scenarios also connect to students' background knowledge and interests. Just as Critical Feature 2.7 described the importance of relevant and authentic phenomena and problems for learning, assessment design can also focus on relevant and authentic phenomenon- and problem-based scenarios to monitor student learning. These kinds of connections are linked with increases in student performance on assessments. As an illustration, a classroom assessment scenario could describe a local erosion problem in the community, emphasizing the effects on the lives of community members. The task could then ask students to propose solutions to the problem and describe, in a modality of their choice, the mechanism of the solution.

Coherent tasks. Just as it's important for a unit to be sequenced coherently so it makes sense to students, high-quality assessment tasks are also designed with coherence in mind. Student curiosity about phenomena or problems can motivate a student to complete a task, and if it is designed with connected prompts that are relevant to the overall sense-making or problem solving, then students will know why they're doing what they're doing in each part of the task.

Critical Feature 3.3: Including scoring guidance and supporting teachers to provide feedback related to student use of the three dimensions

SCORING GUIDANCE AND FEEDBACK ARE	
LESS LIKE...	**MORE LIKE...**
Simple answer keys. Answer keys provide only right or wrong answers for prompts, are general rather than prompt-specific, or only support category-level (e.g., "Developing and Using Models," "Cause and Effect") interpretations of student performance rather than interpretations related to grade-specific elements.	**Specific answer keys support interpretation of a range of student proficiency in targeted dimensions** Prompt-specific scoring guidance helps teachers determine student progress in the grade-specific element learning goals for each of the three targeted dimensions. For instance, scoring guidance may offer a range of student responses to demonstrate proficiency or qualities of answers. This helps the teacher understand different levels of student proficiency for each of the three dimensions and provides enough information that teachers would be able to adjust instruction according to individual student needs.
Unproductive or absent guidance for feedback and adjusting instruction. Suggested feedback to students is corrective (e.g., simply telling them the right answer) or opportunities for peer or teacher feedback are missing. Guidance for modifying instruction based on assessment results is absent or limited to reteaching.	**Guidance for feedback and adjusting instruction.** Materials provide guidance to prompt both teacher and peer feedback on student performance and include support for student self-reflection based on the feedback. Suggestions are provided for how teachers could respond to individual student needs related to each grade-specific element learning goal as identified by the assessment results.
Scoring penalizes errors unrelated to the assessment targets. The scoring guide penalizes errors outside of the learning goals (e.g., grammatical or spelling errors).	**Scoring is specific to assessment targets**. Scoring rubrics focus on student use of the three dimensions for sense-making and problem solving. Materials support teachers to provide feedback, rather than scoring, for issues outside of the learning goals, such as grammatical errors.

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In high-quality materials, assessments target grade-appropriate elements of the three dimensions to ensure teachers can see what and when students are learning.

Support for a range of three-dimensional student responses. In high-quality materials, assessments target grade-appropriate elements of the three dimensions to ensure teachers can see what and when students are learning. Detailed scoring guidance can show different levels of student knowledge and ability with using the SEPs, CCCs, and DCIs by supporting teachers to interpret a range of student responses. This is important to students so that they have an opportunity to see how they are building towards the learning goals for each dimension. For each question within a task, this may look like:

- separate examples or descriptions of different proficiency levels of student responses for each grade-specific element of the learning goals; or
- examples of multidimensional answers at different proficiency levels with guidance for the teacher to distinguish between the targeted dimensions within the examples.

Grade-appropriate specificity. In materials reviewed by EdReports and NextGenScience, many of the assessment components currently present scoring guidance to teachers through a generic rubric without specifications for each individual assessment target. When present, rubrics for SEPs or CCCs often lack details specific to grade-appropriate elements targeted by the assessment, as well as expectations for student responses related to specific prompts, making it more difficult for both the teacher and student to identify progress toward learning goals. Accurate claims of student performance can only be made if the element-level focus of the assessment is clearly articulated. Although there are many ways to communicate the specificity of an assessment's design, one approach is illustrated below that shows an element-specific focus of scoring guidance.

SUMMATIVE ASSESSMENT: LIGHT INVESTIGATIONS [GRADE 1]

Investigation 1: Students are prompted to identify three objects placed near a wall after the teacher turns the lights out in a room without windows. Then, students attempt to observe the objects.

Investigation 2: Next, the teacher shines a flashlight directly on one of the three objects and asks students to make and record additional observations.

Investigation 3: The teacher then turns the lights completely on and asks students to make and record observations again.

Final Summary: Students are prompted to review their observations and describe how the different stages of light affected their ability to observe the object and to determine which stage of light was the easiest, which was the hardest, and why. Students are also asked to compare evidence from their observations to their initial ideas about what would happen.

This assessment provides evidence for students in building toward the following performance expectation:

- 1-PS4-2 Make observations to construct an evidence-based account that objects in darkness can be seen only when illuminated.

Three-Dimensional Assessment Targets (Element-level focus, with prioritization indicated in **bold**)	DCI: PS4.B: Electromagnetic Radiation: **Objects can be seen if light is available to illuminate them** or if they give off their own light. (1-PS4-2) SEP: Constructing Explanations and Designing Solutions **Make observations (firsthand** or from media**) to construct an evidence-based account for natural phenomena.** (1-PS4-2) CCC: Cause and Effect Simple tests can be designed to **gather evidence to support or refute student ideas about causes.** (1-PS4-2)
Qualities that determine student proficiency in response:	A **proficient** student response describes: A. the darkness and inability to observe objects in terms of no or little light [DCI], B. the light sources as where the light comes from and the cause for the ability to observe the objects) [SEP & DCI], C. that different amounts of light may cause different results (e.g., the more light you use, the more you can see) [SEP & DCI], D. difference in brightness across areas of the room when the flashlight is used and the amount of light reaching a single object versus the other two that receive indirect light [SEP & DCI],

Qualities that determine student proficiency in response (continued):	E. ability to observe all three objects when classroom lights are on because of the amount of light reaching all surfaces [SEP & DCI], F. that their observations under all three investigation conditions provide them with evidence to be able to determine why they couldn't see the objects with the lights off [SEP, CCC, & DCI], and G. a statement about whether their observations supported their initial ideas about the causes of seeing things well [SEP, CCC, & DCI]. A student response **approaching proficiency** may include one or more of the following descriptors in place of the corresponding proficient-level descriptor: A. the darkness and change in appearance of objects when there is no or little light [DCI], B. the light sources, as where the light comes from [DCI], C. that there is a relationship between different amounts of light and seeing more [SEP & DCI], D. difference in brightness across areas of the room when the flashlight is used [SEP & DCI], E. the appearance of all three objects when classroom lights are on [SEP & DCI], F. that their observations under all three investigation conditions help them determine which stage of light made it easiest to see the objects [SEP, CCC, & DCI], and G. a comparison of their observations to their initial ideas about the causes of seeing things well [SEP, CCC, & DCI]. An **entry level** student response may include one or more of the following descriptors in place of the corresponding proficient-level descriptors: A. a mention that one of the conditions was in the dark [DCI], B. no mention of the light source [DCI], C. no explicit description of a relationship between amounts of light and amount you can see [SEP & DCI], D. a mention of what was seen with the flashlight [SEP & DCI], E. a mention of what was seen when classroom lights are on [SEP & DCI], F. a description of which stage of light made it easiest to see the objects (but no mention of observations) [SEP & DCI], and G. listing initial ideas but not connecting them to observations [DCI].

SUMMATIVE ASSESSMENT: LIGHT INVESTIGATIONS [GRADE 1] (CONTINUED)	
Guidance for teachers to support students in their response:	The teacher may use the following questions and statements to clarify and support all students during the investigation conditions. • When I shine the flashlight, why does one object look bright and the other object does not? • Why is this area bright and this area is dark? • When I turn on the lights, how does the brightness change? • In each stage of the investigation, ask, where does the light come from? • Think about how your initial ideas may be similar or different from what you are seeing in each investigation. During the 1:1 student explanation, if students cannot explain how the investigations provided evidence to support or refute their initial ideas, consider asking the following questions to ensure students demonstrate understanding and use of the CCC: • How did the three investigations help us explain how we can see the objects? If that prompts the students to explain the relationship between the investigation and evidence acquired for the explanation, then they are showing evidence of the ability to use that CCC to explain the phenomenon. • How do your initial ideas compare to your observations of what happened? Did the observations change your ideas? If that prompts students to compare the observations to their initial ideas and to say whether it supported or refuted their claim, they are showing evidence of their ability to use that CCC.

Importance of feedback support. Feedback is important for students to understand their own progress and to consider what is needed to move towards proficiency. High-quality materials provide specific guidance about what kind of feedback will support student learning toward each of the targeted three dimensions and identify opportunities to provide that feedback to students. Materials reviewed by EdReports and NextGenScience often have missed opportunities for students to receive feedback from both peers and the teacher, and to reflect on and apply that feedback to improve their performance on all three dimensions in an iterative process, especially with regard to performances using the CCCs. For instance, feedback guidance, when present, often prompts discussion of accurate DCI understanding and major features of an SEP, but feedback on students' application and understanding of CCCs is rarely prompted.

Adjusting instruction based on student responses. High-quality materials support teachers not only to provide feedback to students, but also to adjust and improve instruction in response to information acquired through student assessments. As students progress through the learning sequence towards summative assessment, formative assessment checkpoints can support teachers to be able to diagnose student trajectory and respond accordingly to ensure they are best prepared to demonstrate their use of the three dimensions in a formal setting. For instance, materials may prompt educators to:

- collect and analyze student responses to identify common challenges, paired with working solutions, to ensure they can support students across a range of proficiencies in each targeted element,
- identify necessary future instruction to support students, or
- reflect on and modify instruction for the future in response to the student assessment information and interpretation of student responses over time.

Student reflection and self-assessment. In addition to supporting teachers to monitor student learning, high-quality materials support students in reflecting on and monitoring their own learning. Student opportunities to recognize and explicitly reflect on how their prior understandings have changed over time and to compare their current performance to overall learning goals can increase their agency over their own learning and help them understand where they need to go next. High-quality materials give students these crucial reflection opportunities, such as through metacognitive supports and prompts to reflect on feedback and to compare their performance to rubrics.

Critical Feature 3.4: Designing a coherent assessment system

COHERENT ASSESSMENT SYSTEMS ARE	
LESS LIKE...	MORE LIKE...
Unspecified assessment targets. It is unclear what learning goals are targeted in specific assessments, making it difficult to see how all assessments work together to form a coherent system. For instance, assessment tasks only specify targeted dimensions at the category level (e.g., "CCC = Cause and Effect") rather than at a grade-appropriate element-level, typically prompting student performances below the intended grade level.	**Comprehensive and clear assessment targets.** Assessments target specific aspects of the learning goals at the element level for each of the three dimensions, and these assessment targets are clearly specified for teachers and administrators. Together, the assessments create an assessment system that consistently and coherently monitors student use of the three dimensions and supports the use of that data to help students reach their learning goals.
Single opportunities to demonstrate proficiency. The assessment system gives students just one opportunity to demonstrate proficiency for each targeted learning goal.	**Multiple opportunities to demonstrate proficiency.** The assessment system gives students multiple opportunities to demonstrate proficiency for each targeted learning goal, particularly for SEPs and CCCs, which benefit from student use in multiple contexts.
Unclear or conflicting assessment system goals and purposes. Materials don't describe the intended purposes and roles of each assessment within the larger assessment system and how they work together to provide a complete picture of student learning. Materials list assessment targets that are separate from the learning goals, with no clear guidance for teachers to reconcile the two.	**Transparent assessment system.** Materials include background information on how different assessments are intended to be used together to support understanding of student progress over time towards learning goals and larger performance expectations. Materials support teachers to see connections between assessment targets, instructional activities, and overall learning goals.

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High-quality materials support teachers to see how the goals for the learning, instructional activities, and assessments are connected.

Clear connections between learning goals, activities, and assessments and how they build over time. High-quality materials support teachers to see how the goals for the learning, instructional activities, and assessments are connected. The assessments together provide multiple opportunities for students to demonstrate their progress toward all learning goals.

The shorter-term (e.g., lesson- or unit-level) learning goals, activities, and assessments build coherently toward the longer term (e.g., program-level) performance expectations. The assessment system is explicitly designed to support the student in progressing towards the learning goals, with opportunities for teachers to understand the progression and connection between the goals, activities, and assessments over the course of the entire year.

Clear explanation of how multiple assessment types work together over the full program or learning experience. An assessment system also includes varied forms of assessment with differing purposes, including pre-assessments, formative assessment processes, summative assessments, and student self-reflection. In high-quality materials, the types, purpose, organization of assessments, and the overall system are clear to teachers.

Assessments work together to measure proficiency toward three-dimensional performance expectations. High-quality assessments are part of a system that monitors progress towards the learning goals and demonstrates coherence for the teachers and students. The assessment system includes:

- multiple opportunities for students to demonstrate proficiency in or progress towards all grade-specific element learning goals that create the targeted three-dimensional performance expectations,
- clear communication of the element-level assessment targets for each part of the assessment system (e.g., formative progress checks, summative assessments), and
- descriptions of the role of each assessment in monitoring student progress toward the performance expectations by the end of the grade or grade band.

Assessing all learning goals. Although assessments in reviewed materials commonly include multi-dimensional assessment items, many assessments do not fully assess the learning goals claimed for the instructional sequence. Often, all learning goals are not fully assessed because they are claimed in a broad way that does not accurately reflect what students are learning, as mentioned in Critical Feature 1.1.

Currently, materials reviewed by EdReports and NextGenScience inconsistently include a complete assessment system that coherently monitors and supports student progress toward all targeted learning goals throughout each unit and larger learning sequence. In particular, the grade-specific portions of the SEPs and CCCs in the learning goals are less likely to be monitored and supported than those for the DCIs throughout the components of the assessment system, resulting in a disproportionate focus on DCIs throughout learning and assessment. All three dimensions are equally important and therefore need to be equally assessed.

In the following illustration, an assessment system was designed to monitor students’ progress towards the identified performance expectations targeted by the instructional unit. The table shows that the assessments are built to provide multiple opportunities for students to demonstrate full and partial proficiency in the DCI, SEP, and CCC learning goals. This illustration shows the element level of the dimensions as both learning goals and assessment targets, indicating alignment of the two. Each assessment opportunity includes three dimensions and notes how each element is addressed across the larger assessment system designed for the entire year.

There are many ways to design an assessment system. The following illustration is an overview to show aspects of the system. Because it is only an illustration, it lacks specificity of the actual tasks and the teacher support required to respond to the assessment tasks. The level of detail shown in this table would not be needed for each task. Instead, tables or other kinds of assessment system guidance are most helpful when they support planning across tasks in a unit, including showing an element-level focus, how these tasks demonstrate students building towards performance expectations, and the connections and coherence between multiple assessment opportunities.

ILLUSTRATION OF A UNIT ASSESSMENT SYSTEM

Unit 1 Targeted Performance Expectations	MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. *Students build toward these performance expectations in Unit 1. See the future connections listed in the following columns to determine subsequent learning and assessment opportunities.*
Lesson 1 Assessment Opportunities and Learning Goals Assessed	Lesson 1 Progress Check Learning and Assessment Targets: DCI: ESS2.A: **The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history** and will determine its future. *In this formative instance, students use a model to describe interactions of the earth, but do not make predictions until Lesson 3 and in the Unit 1 Assessment where this entire element is summatively assessed.* SEP: MOD: Develop and **use a model to describe phenomena** *In this lesson, modeling is limited to the use of models in the lesson and formative assessment. Later, Unit 4 builds on this practice and provides students an opportunity to develop and use models, with the summative assessment for this practice present in Unit 4, Lesson 5.* CCC: SPQ: **Time**, space, and energy **phenomena can be observed** at various scales **using models** to study systems that are too large or too small. *In this lesson, students examine a single scale to examine time phenomenon through the use of models. Later, Units 2 and 4 provide opportunities for students to utilize models to encounter and explain space and energy phenomena at macro and micro scales.*

ILLUSTRATION OF A UNIT ASSESSMENT SYSTEM (CONTINUED)

Lesson 2 Assessment Opportunities and Learning Goals Assessed	Lesson 2 Progress Check Learning and Assessment Targets: DCI: LS2.A: **Organisms, and populations of organisms, are dependent on their environmental interactions** both with other living things and with **non-living factors.** *In this formative instance, students analyze and interpret data related to only non-living factors. Later, Unit 3, Lesson 3 provides an opportunity for students to be summatively assessed on the aspect of living things in the context of this element.* SEP: DATA: **Analyze and interpret data to provide evidence for phenomena** *In this lesson, students get feedback on their use of this element. Later, this element is summatively assessed in Unit 2, Lesson 2.* CCC: PAT: **Patterns can be used to identify cause-and-effect relationships** *In this lesson, students get feedback on their use of this element. Later, this element is summatively assessed in Unit 2, Lesson 2.*
Lesson 7 Assessment Opportunities and Learning Goals Assessed *[Lessons 3–6 not shown in this illustration]*	Unit 1 Assessment Task Learning and Assessment Targets: DCI: ESS2.A: **The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.** *This element is fully assessed by this summative assessment.* DCI: LS2.A: **Organisms and populations of organisms are dependent on their environmental** interactions both with other living things and **with non-living factors**. *The bolded parts of this element are summatively assessed. The aspect of interactions with other living things is assessed later, in Unit 2, Lesson 4.*

ILLUSTRATION OF A UNIT ASSESSMENT SYSTEM (CONTINUED)

Lesson 7 Assessment Opportunities and Learning Goals Assessed (continued) *[Lessons 3–6 not shown in this illustration]*	SEP: CEDS: **Apply scientific ideas, principles, and/or evidence to construct,** revise and/or use **an explanation for real-world phenomena**, examples, or events. *The bolded parts of this element are summatively assessed. In Unit 2, Lesson 4 students have opportunities to demonstrate their ability to both revise and use explanations for real-world phenomena.* *NOTE: Constructing an explanation here uses a different element than the one paired with the performance expectation MS-ESS2-2, which is present and assessed in Unit 2, Lesson 4.* CCC: CE: **Cause-and-effect relationships may be used to predict phenomena in natural or designed systems** *The bolded parts of this element are summatively assessed. Later, cause-and-effect relationships for designed systems are used by students throughout Unit 5 and are summatively assessed in the Unit 5 Engineering Project.*

Glossary

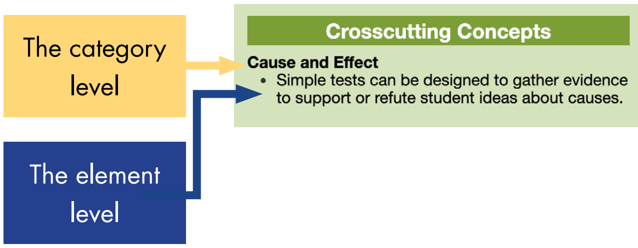
Assessment system — Multiple, varied assessment opportunities designed to answer different kinds of questions (e.g., those designed to support teaching and learning in the classroom, those designed to support programmatic and policy decisions).

Crosscutting Concepts (CCCs) — CCCs are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and make sense of phenomena or solve problems.

Disciplinary Core Ideas (DCIs) — DCIs are the fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

Driving questions — The point of using phenomena and problems to drive instruction is to help engage student curiosity, motivating them to want to figure out the phenomenon or solve the problem. Therefore, the focus is not just on the phenomenon itself, it is the phenomenon plus the student-generated questions about the phenomenon that guides the learning and teaching.

Elements/element-level vs. category-level — Elements are the bulleted SEPs, DCIs, and CCCs that are articulated in the foundation boxes of the standards as well as in the NGSS appendices on each dimension. Elements are different for each grade band. Categories are the names of the eight SEPs, seven CCCs, and 41 DCIs (e.g., ESS3.B Natural hazards), and repeat across grade bands.



Formative assessment — Formative assessment is a process used by teachers and students *during instruction* that provides feedback to adjust ongoing teaching and learning to improve students' achievements of intended instructional outcomes.

Full science program — A program is defined in this document as the full set of units for the science disciplines for a grade band: K–2, 3–5, 6–8, or 9–12.

Performance expectations — The NGSS, and many similar standards, are written as a set of expectations for what students should be able to do by the end of instruction (years or grade bands). The performance expectations set the learning goals for students, but do not describe how students get there.

Science and Engineering Practices (SEPs) — The practices are what students do to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs in today's science standards reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Sense-making — The process by which students build evidence-based explanatory ideas that help them figure out phenomena.

Summative assessment — The goal of summative assessment is to evaluate student learning at *the end of instruction* by comparing it against some standard or benchmark.

Task — An activity that provides students an opportunity to demonstrate learning of a particular learning target. A task may be formative, summative, and could include multiple steps, prompts, or questions.

Three-dimensional learning — When students develop and use elements of the three dimensions together to explain phenomena or design solutions to problems, they learn three-dimensionally. Instructional materials aligned to the standards are three dimensional. That is, they allow students to actively engage with the practices and apply the CCCs to deepen their understanding of core ideas across science disciplines.

Using/applying elements (reinforcing prior learning) vs. developing elements — Elements that are merely used are not necessarily learning goals. Students do not need to learn something new in order to apply their prior learning. Elements that are developed are learning goals. Students may be learning them from scratch or may be developing a new understanding of part of the element or how it can be applied.

About the Authors

EdReports is an independent nonprofit designed to improve education by providing free reviews of K–12 instructional materials led by expert educators. EdReports works to increase the capacity of teachers, administrators, and leaders to seek, identify, and demand the highest quality instructional materials.

NextGenScience supports states, districts, educators, and other partners to design and identify quality, coherent programs that align science standards, instructional materials, professional learning, and assessments. NextGenScience was formerly the science team at Achieve — the nonprofit organization that coordinated the development of the Next Generation Science Standards (NGSS) — and continues Achieve's work with NGSS stewardship and implementation, including by coordinating reviews of materials.

The two organizations have different but complementary roles in science instructional materials development and the review ecosystem. EdReports provides reviews of comprehensive core instructional materials and publishes all programs reviewed on its website. NextGenScience provides extensive formative feedback on instructional units through confidential, iterative review cycles. Only reviews of the top-rated instructional units in this process are made public. Both organizations support states and districts in utilizing reviews to adopt aligned materials that can work best for their students.

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