## Innovation 2: Three-Dimensional Learning

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| **Summary** | Students making sense of phenomena or designing solutions to problems *requires* student performances that integrate elements of the SEPs, CCCs, and DCIs in instruction and assessment. |

From the *Framework*:

Instructional materials must provide a research-based, carefully designed sequence of learning experiences that develop students’ understanding of the three dimensions and also deepen their insights in the ways people work to seek explanations about the world and improve the built world.

That there are three dimensions in the standards—the science and engineering practices (SEPs), the disciplinary core ideas (DCIs), and crosscutting concepts (CCCs)—is probably the most immediately apparent innovation in the NGSS, but there is important and often-missed subtlety in the three-dimensionality that is of particular importance for instructional materials designed for the NGSS. The subtlety is highlighted in the three parts of this innovation:

1. ***Three Dimensions***—all three dimensions are equally important learning outcomes.
2. ***Integrating the Three Dimensions in Instruction***—the three dimensions need to work together and not be taught in isolation.
3. ***Integrating the Three Dimensions in Assessment***—monitoring student learning should focus on tasks and assessments that integrate the three dimensions.

### **Part A: Three Dimensions**

In the NGSS, all [three dimensions](http://www.nap.edu/openbook.php?record_id=13165&page=3) of the *Framework* represent equally important learning outcomes ([Next Generation Science Standards](http://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states), 2013). Though the precursors of each of these dimensions existed in past science standards in many states, they were not valued equally. Giving them equal footing as learning outcomes is an innovation of the NGSS.

Prior to the NGSS, the bulk of most state standards documents identified “science content” expected for students to know or understand. This “science content” was the precursor of *disciplinary core ideas*. In practice, the “regurgitation” of details often became a proxy for evaluating student conceptual understanding. Because of the sheer breadth of detailed information, most instructional materials and the instruction they supported focused on creative ways to disseminate this information to students, rather than on students building a deep conceptual understanding of disciplinary core ideas that they could use to make sense of the world.

Many state standards also included at least one standard that highlighted what students needed to know about how scientists do their work—the precursor to the *science and engineering practices*. Often called “inquiry,” this led off many state standards documents. Not surprisingly, it was frequently also the first chapter in textbooks based on the standards and was taught in classrooms as an introductory unit separate from any learning about “science content.” The separation of skills and knowledge in instructional materials combined with a much larger proportion of the standards being focused on “science content” led to an emphasis (in both instruction and assessment) on “science content.” In addition, when inquiry was included, inquiry skills were often superficial and did not build in complexity over time; there were not many differences in the expectations of elementary and secondary students, and often no clear and supported progression within grades or grade-bands for developing the knowledge and skills associated with inquiry targets.

Not quite as common—but still included in many state standards documents—were references to ideas derived from the “[Unifying Concepts and Processes](https://www.nap.edu/read/4962/chapter/8)” of the [National Science Education Standards](https://www.nap.edu/catalog/4962/national-science-education-standards)(NRC 1996), the “[Common Themes](http://www.project2061.org/publications/bsl/online/index.php?chapter=11)” of the *Benchmarks for Science Literacy* (AAAS 2009), “themes” in [Science for All Americans](https://www.aaas.org/report/science-all-americans) (AAAS 1989), and “crosscutting ideas” NSTA’s Science Anchors Project (2010). These ideas—the precursor to the *crosscutting concepts*—were frequently addressed either in the front matter of the standards documents and/or were buried in standards that were viewed to be supplemental to core learning. Though they were often passively and implicitly included in science teaching and learning, there was generally little emphasis on them in learning goals for students.

Though these dimensions are similar to what has been in past standards in many states, what is addressed in each of these dimensions has significant changes based on the *Framework.* In addition, setting them as equally valuable learning goals is significantly different than how the three dimensions have been historically handled in instructional materials—both science content and scientific endeavor are essential components of the knowledge and skills students need for success. The science and engineering practices and crosscutting concepts are not in the service of the acquisition of the disciplinary core ideas, rather all three dimensions are used in service of students making sense of the world they live in. Instructional materials designed for the NGSS must be designed in a way that communicates this equal value while also clearly and methodically building student proficiency in all three dimensions over the course of the program.

### **Part B: Integrating the Three Dimensions in Instruction**

Building student proficiency in all three dimensions is a significant innovation all by itself, but the implication of this innovation goes beyond three separate strands of learning that are equally valued. The fact that these standards are written as three-dimensional performance expectations is significant and intentional, and should be reflected in the learning experiences within instructional materials. The *Framework* makes it clear that, “In order to achieve the vision embodied in the framework and to best support students’ learning, all three dimensions need to be integrated into the system of standards, curriculum, instruction, and assessment” (2012). Students develop and apply the skills and abilities described in the practices, as well as use the CCCs to make sense of phenomena and make connections between different DCIs in order to help gain a better understanding of the natural and designed world. To accomplish this, instructional materials designed for the NGSS must be anchored with integrated three-dimensional student performances. Simply parsing these dimensions back out into separate entities to be learned and assessed in isolation misses the vision of the NGSS and the *Framework*.

It is important to highlight that the standards were designed to be *endpoints* for a grade level (K*–*5), or grade band (6*–*8; 9*–*12) and that they collectively describe what students should know and be able to do—not *the only* performances students should experience. As such, the exact pairings of the dimensions in the standards should not limit how the dimensions are integrated during classroom instruction and assessment. That these standards are not intended to be curriculum is not necessarily a unique innovation—prior standards weren’t curriculum either—but it is highlighted here to avoid potential misinterpretations of the three-dimensional performance expectations in the NGSS. Because the very architecture of the NGSS models three-dimensionality, the standards themselves may end up *seeming like* a classroom lesson or unit, but it is absolutely **not** the intent of the standards to have students simply “do the standards.” Such an endeavor would be impractical and inefficient as many standards (and parts of standards) overlap with and connect to each other, but since the standards are written as grade level endpoints, they often contain elements of the dimensions that should be taught at different times of the year. For example, a standard may include a foundational DCI that makes sense to address early in the year, but a more advanced level of a CCC or SEP that students might not be prepared to achieve until the end of that same year (or end of the grade band). The NGSS performance expectations explicitly do **not** specify or limit the intersection of the three dimensions in classroom instruction. Instead, three-dimensional learning experiences that integrate multiple SEPs, CCCs, and DCIs will be needed to help all students build the needed competencies toward the targeted performance expectations.

Instructional materials designed for this innovation of the NGSS need to build student understanding across all three dimensions in a way that moves student proficiency toward the standards and helps educators track that progress. It should be clear which elements of the three dimensions are targeted by a lesson or unit, and how student progress will be measured across the three dimensions.

### **Part C: Integrating the Three Dimensions in Assessment**

In addition to integrating the three dimensions in student learning experiences, high quality instructional materials designed for the NGSS will integrate the three dimensions when student progress is being measured throughout their embedded formative and summative assessments. This means more than just an occasional three-dimensional assessment task here or there, or assessments designed to measure one dimension at a time. The focus of measuring student learning should utilize items and tasks that are measuring the dimensions together—in pre-assessments, formative assessments, and summative assessments. Three-dimensional assessment tasks should be embedded throughout instructional experiences, taking advantage of the rich opportunities that are part of instruction during which students make their thinking visible to themselves, their peers, and educators.

Assessment tasks must be designed to provide evidence of students’ ability to use the SEPs, to apply their knowledge of CCCs, and to draw on their understanding of DCIs, all in the context of addressing specific problems or answering certain questions (National Research Council 2014). Instruction and assessments must be designed to support and monitor students as they develop increasing sophistication in their ability to use SEPs, apply CCCs, and understand DCIs as they progress through the year and across the grade levels. As in instruction, the focus of classroom level assessments should be tasks that integrate the dimensions in student performances. Although factual knowledge is fundamental and understanding the language and terminology of science is important, tasks that demand only declarative knowledge about practices or isolated facts would be insufficient to measure performance expectations in the NGSS (National Research Council 2014).

Effective assessment of three-dimensional science learning requires more than a one-to-one mapping between the NGSS performance expectations and assessment tasks. It is important to note that more than one assessment task may be required to adequately assess students’ mastery of some three-dimensional targets, and any given assessment task may assess aspects of more than one performance expectation. In addition, to assess both understanding of core knowledge and facility with a practice, assessments may need to probe students’ use of a given practice in more than one disciplinary context. To adequately cover the three dimensions, assessment tasks will generally need to contain multiple components (e.g., a set of interrelated questions). Developers might focus on individual SEPs, DCIs, or CCCs in some components of an assessment task, but together, the components need to support inferences about students’ three-dimensional science learning as described in a given set of three-dimensional learning targets.

For an introduction regarding assessments and the NGSS, see [*Seeing Students Learn Science: Integrating Assessment and Instruction in the Classroom*(2017)](https://www.nap.edu/read/23548), the STEM Teaching Tool [practice briefs on assessment](http://stemteachingtools.org/tgs/Assessment), and Developing Assessments for the Next Generation Science Standards.

For some more concrete examples of what *Innovation 2: Three-Dimensional Learning* looks like in instructional materials programs, see Table 2.

Table : NGSS Innovation 2—Three-Dimensional Learning

High quality instructional materials programs designed for the NGSS include:

| **Less** | **More** |
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| Using science practices and crosscutting concepts only to serve the purpose of acquiring more science information—valuing the DCI dimension over the others. | Careful design to build student proficiency in all three dimensions of the standards.Student performances where the three dimensions intentionally work together to explain phenomena or design solutions to problems. |
| Students learning the three dimensions in isolation from each other, i.e.:* A separate lesson or unit on science process/methods followed by a later lessons or units focused on delivering science knowledge.
* Including crosscutting concepts only implicitly, or in sidebars with no attempt to build student proficiency in utilizing them.
* Rote memorization of facts and terminology; providing discrete facts and concepts in science disciplines, with limited application of practice or the interconnected nature of the disciplines.
* Prioritizing science vocabulary and definitions that are introduced before (or instead of) students develop a conceptual understanding.
 | Integrating the SEPs, CCCs, and DCIs in ways that instructionally make sense, as well as inform teachers about student progress toward the performance expectations, including:* Students actively engaged in scientific practices to develop an understanding of each of the three dimensions.
* CCCs are included explicitly, and students learn to use them as tools to make sense of phenomena and make connections across disciplines.
* Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
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| Teachers posing questions with only one correct answer. | Teacher questions elicit the range of student understanding.Students discussing open-ended questions that focus on the strength of evidence used to generate claims. |
| Only taking a snapshot of student understanding through summative assessments.…administering additional assessments during instruction (e.g., vocabulary checks) that lack a clear feedback process to monitor and/or move student experiences to meet targeted learning goals.  | Formative assessment processes embedded into instruction to capture changes in student thinking over time and adjust instruction |
| Assessments that focus on one dimension at a time and are mostly concerned with measuring students’ ability to remember information. | Assessments within the instructional materials reflect each of the three distinct dimensions of science and their interconnectedness. |