K-12 Science Learning Best Practice Guide

Cultivating Curiosity, Joy, and Advancing Scientific Knowledge and Practices Through Equitable Teaching and Learning

OREGON DEPARTMENT OF EDUCATION

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Vision for K-12 Science Education

The vision for K-12 science education in Oregon aims to provide each and every student with high-quality, three-dimensional instruction, inspiring future generations of scientifically literate individuals. Science is vital to understanding today's complex world and solving tomorrow's challenges. Connecting learning to students' interests and experiences is crucial for broadening participation in science. The *K-12 Science Education Best Practice Guide* is designed to support the implementation of a high-quality science education program.

Moving Towards Equity-Driven Science Learning Instruction

Science Education Will Involve **Less Of**:	Equity-Driven Science Education Will Involve **More Of**:
Students developing ideas to apply learning before phenomena is selected or introduces.	Teaching through phenomena-based investigations builds usable, applicable knowledge and avoids decontextualized understanding for students.
Rote memorization of facts and terminology	Acquiring knowledge and terminology as needed to develop explanations and design solutions through evidence-based arguments and reasoning.
Students reading textbooks and answering questions at the end of the chapter.	Actively involve students through phenomena-based investigations, collaborative projects, and opportunities for decision-making.
Pre-planned outcome for prescribed laboratories or hands-on activities.	Integrating science concepts with students' lived experiences and diverse cultures to create a sense of relevance and engagement.
Teacher-centered lecture and instruction, with some lab activities.	Students engaging in discourse by working in groups using open-ended questions about evidence, conduct investigations, solving problems, and participating in teacher-guided facilitation.

Designing Equitable Teaching and Learning in Science Education

Effective science instruction engages students in making sense of the world around them, asking meaningful questions, exploring and investigating ideas, and collaboratively creating authentic artifacts that demonstrate standards-based learning.

Science learning should be student-centered and consistently engage students in the practices of science and engineering. Instruction should foster collaborative sensemaking — **a critical component of understanding phenomena and solving problems — while valuing and reflecting student interest and identity.**

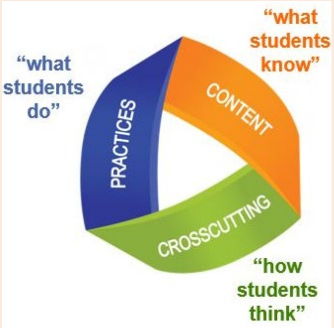
All students, including elementary students, should experience high-quality science instruction regularly. Ensuring educators have time, resources, and support to engage all students in meaningful science experiences is critical for expanding access to science, fostering curiosity, and cultivating a scientifically literate society.

Three Distinct and Equally Important Dimensions to Learning Science

A K–12 Framework Science Education describes a vision of what it means to be proficient in science. It rests on a view of science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge. The Framework presents **three dimensions that are combined to form each K-12 science standard**.

These **three dimensions** are disciplinary core ideas, science and engineering practices, and crosscutting concepts. Each dimension makes up distinct but **equally important components** of what students should know and be able to demonstrate. This helps students **build cohesive understanding of science over time**.

Three-Dimensional Learning: Putting it Together



The **three dimensions** are:

- **Dimension 1: What Students Do**: Science and Engineering Practices
- **Dimension 2: How Students Think:** Crosscutting Concepts
- **Dimension 3: What Students Know:** Disciplinary Core Ideas

Three-Dimensional Learning: Putting it Together

Dimension 1: Science and Engineering Practices

The practices describe **behaviors that scientists engage in** as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems. *A Framework for K-12 Science Education* **uses the term "practices" instead of a term like "skills" to emphasize that engaging in scientific investigation** requires not only skill but also the knowledge that is specific to each practice.

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

- **Asking Questions and Defining Problems**
  A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested.

- **Developing and Using Models**
  A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

- **Planning and Carrying Out Investigations**
  Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

- **Analyzing and Interpreting Data**
  Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results.

- **Using Mathematics and Computational Thinking**
  In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships.

- **Constructing Explanations and Designing Solutions**
  The end-products of science are explanations, and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has been extensively tested and is well-supported by a large body of empirical evidence and greater explanatory power of phenomena than previous theories.

- **Engaging in Argument from Evidence**
  Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem.

- **Obtaining, Evaluating, and Communicating Information**
  Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Three-Dimensional Learning: Putting it Together

Dimension 2: Crosscutting Concepts

Crosscutting Concepts
1. Patterns 2. Cause and Effect 3. Scale, Proportion, and Quantity 4. Systems and System Models 5. Energy and Matter 6. Structure and Function 7. Stability and Change

Crosscutting concepts have application across all domains of science. As such, **they are a way of linking the different domains of science**. A Framework for K-12 Science Education emphasizes that these concepts need to be made explicit for students because they **provide an organizational schema for interrelating knowledge** from various science fields into a coherent and scientifically-based view of the world.

- **Patterns**
  Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
- **Cause and Effect: Mechanism and Explanation**
  Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
- **Scale, Proportion, and Quantity**
  In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
- **Systems and System Models**
  Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
- **Energy and Matter: Flows, Cycles, and Conservation**
  Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
- **Structure and Function**
  The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
- **Stability and Change**
  For natural and built systems alike, conditions of stability and factors that control rates of change are critical elements to consider and understand.

Three-Dimensional Learning: Putting it Together

Dimension 3: Disciplinary Core Ideas

Disciplinary core ideas have the power to focus K–12 science curriculum, instruction, and assessments on the most important aspects of science. To be considered core, the ideas should meet at least two of the following criteria and ideally all four:

- Have **broad importance** across multiple sciences or engineering disciplines, or be a **key organizing concept** of a single discipline;
- Provide a **key tool** for understanding or investigating more complex ideas and solving problems;
- Relate to the **interests and life experiences of students** or be connected to **societal or personal concerns** that require scientific or technological knowledge;
- Be **teachable** and **learnable** over multiple grades at increasing levels of depth and sophistication.

Disciplinary ideas are grouped in four main core ideas (domains) and their subtopics (subdomains):

- Earth & Space Science
  - ESS1 Earth's Place in the Universe
  - ESS2 Earth's Systems
  - ESS3 Earth and Human Activity
- Engineering, Technology, and the Application of Science
  - ETS1 Engineering Design
  - ETS2 Links Among Engineering, Technology, Science, and Society
- Life Science
  - LS1 From Molecules to Organisms: Structures and Processes
  - LS2 Ecosystems: Interactions, Energy, and Dynamics
  - LS3 Heredity: Inheritance and Variation of Traits
  - LS4 Biological Evolution: Unity and Diversity
- Physical Science
  - PS1 Matter and Its Interactions
  - PS2 Motion and Stability: Forces and Interactions
  - PS3 Energy
  - PS4 Waves and Their Applications in Technologies for Information Transfer

Disciplinary Core Ideas

Life Sciences
LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS3: Heredity: Inheritance and Variation of Traits
LS4: Biological Evolution: Unity and Diversity

Earth and Space Science
ESS1: Earth's Place in the Universe
ESS2: Earth's Systems
ESS3: Earth and Human Activity

Physical Science
PS1: Matter and Its Interactions
PS2: Motion and Stability: Forces and Interactions
PS3: Energy
PS4: Waves and Their Applications in Technologies for Information Transfer

Engineering, Technology and the Application of Science
ETS1: Engineering Design
ETS2: Links Among Engineering, Technology, Science, and Society

Three-Dimensional Learning: Putting it Together

Understanding the K-12 Science Standards Coding

Topic Domain: **Main Disciplinary Core Idea**

Life Science (LS)

LS1 - From Molecules to Organisms: Structures and Processes

5.LS1.1 Support an argument that plants get the materials they need for growth chiefly from air and water.

Specific Grade Level or Grade Band Standard

Topic Subdomain: **Specific Disciplinary Core Idea**

[**Clarification Statement**: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.] [**Assessment Boundary**: Assessment does not include photosynthesis or the photosynthesis reaction equation.]

For the standard above, this text provides **supporting statements** of possible examples or additional information to the standard (performance expectation) and specific limits to assessments.

By the end of grade 5, **students who demonstrate understanding can:**

5.LS1.1 Support an argument that plants get the materials they need for growth chiefly from air and water.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). • Support an argument with evidence, data, or a model.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • Plants acquire their material for growth chiefly from air and water.	**Energy and Matter** • Matter is transported into, out of, and within systems.

Oregon K-12 Science Standards

The State Board of Education adopted the Oregon Science Standards in 2022, which represents the K-12 learning expectations in science education for all students and are the foundational expectations of the Oregon Diploma.

The Oregon K-12 Science Standards set the **expectation for what students should know and be able to do** by the end of each grade level (K-5) or grade band (middle and high school).

There is no doubt that science - and therefore, **science education - is central to the lives of every community member**. Never before has our world been so complex and scientific literacy so critical to making sense of it all. Science is also at the heart of each community's ability to continue innovating, leading, and thrive. That's why **all students** - regardless of whether they pursue college or STEM careers - **should have access to a high-quality K-12 science education.** (nextgenscience.org, 2013)

"**Equity in science education** requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; ... connecting to students' interests and experiences is particularly important for broadening participation in science."

— NRC Framework, 2012, p. 28

Structure of Standards

These are **color-coded example** of a three-dimensional standards with the:

- Disciplinary Core Idea **(DCIs) in orange**
- Science and Engineering Practices **(SEPs) in blue**
- Crosscutting Concept **(CCCs) in green**

Grade Level and Grade Band Examples:

- Elementary School Earth and Space Standard
  3.ESS2.1 Represent data in tables and graphic displays to describe typical weather conditions expected during a particular season.
- Middle School Life Science Standard
  MS.LS2.3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- High School Physical Science Standard
  HS.PS4.1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

For additional information, please visit the Oregon Department of Education Science Webpage.

Centering Student Engagement Using Natural Phenomenon & Authentic Problems

The Framework for K–12 Science Education establishes a vision of **science for all** students, with a goal of developing a scientifically literate society and preparing students with the skills, habits, and understanding needed to be contributing community members as well as college and career ready. The instructional approach called for in the Framework encourages students to **move from learning about** to **observing and figuring out** natural phenomena by investigating and explaining **how and why** these phenomena occur. The Framework provides coherence in science teaching and learning and has set forth a transformative vision of K-12 science education that shifts from historical approaches of rote memorization to a vision for science that cultivates curiosity, wonder, joy, and deeper scientific knowledge and practices.

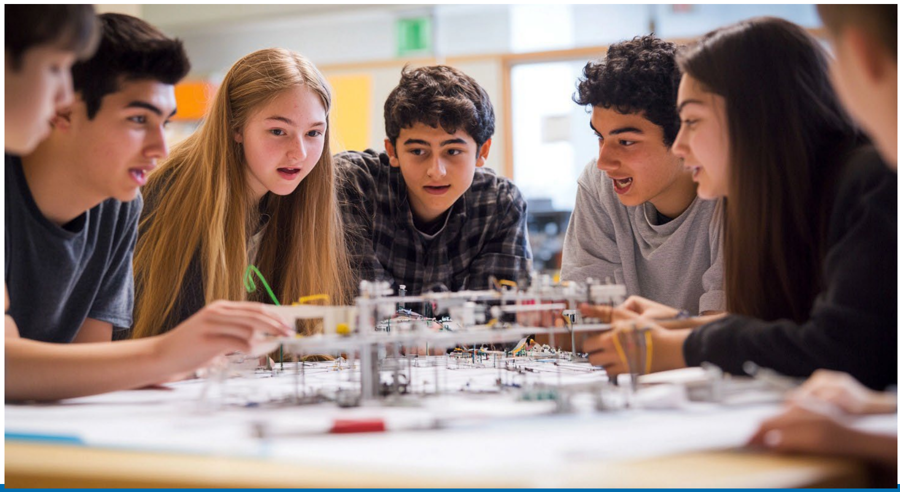
The Oregon K-12 Science Standards are aligned to this vision and the notion of learning as a **developmental progression**. They guide learners to continually expand and revise their knowledge and skills, starting from their natural curiosity and initial ideas about how the world works.

To Foster Student Engagement, Consider the Following:

- Keep science **teaching and learning coherent** by bundling standards and developing science storylines. Use engaging phenomena to address requisite skills and knowledge, focusing on grade-level learning.
- Develop inclusive science instructional opportunities that focus on **leveraging student interests and identity**. Chapter 11 of the Framework for K–12 Science Education highlights how students do not leave their cultural worldviews at the door. Cultural perspectives can transform learning experiences to make them more engaging and meaningful for learners.
- Create **opportunities to engage in class discussions** is essential for students to construct their thoughts in real-time, engage in reasoning, and **make their thinking visible**. A classroom rich in discussion not only enhances individual understanding but also fosters a collaborative learning environment where students refine ideas, challenge misconceptions, and develop discipline-specific ways of thinking.

Use these **reflection questions** independently or with your professional learning communities (PLC) to examine current instructional practices and to engage in future planning.

- Is the anchoring phenomenon related to students' local environment and connected to their lived experiences or to a problem that needs to be solved?
- Are students engaging in scientific and engineering practices while applying disciplinary core ideas and crosscutting concepts to explain phenomena or solve problems?
- Does instruction leverage student identity and interest while fostering meaningful connections to their homes and communities?
- Are tasks or classroom engagements designed to productively move students through sesnsemaking processes?
- Are there multiple opportunities for students to apply their knowledge and skills while deepening the sophistication of their thinking over time?



Equitable Student Engagement in Learning Science

In science, evidence-based effective instruction focuses on students engaging in investigations and engineering design to **explain phenomena** or **develop** solutions to a problem. Science instruction should help students understand **"why does this matter to me?"** By connecting to high-leverage science teaching and learning practices, such as using naturally occurring phenomena, promoting discourse in classrooms, and building on student's interests and identities, educators create inclusive and engaging learning spaces.

These instructional strategies also support Oregon's Transformative Social Emotional Learning Framework and Standards to create conditions for learning and thriving across social contexts, systems, and learning environments. The three themes for a systemic approach to promote the necessary conditions for learning and thriving where every student's social, emotional, and academic needs can be met are: **cultivate authentic partnerships**; **adopt equitable practices**; and **create thriving learning environments**.

Leverage the expertise and resources of community partners including your school or district science leaders, Educational Service Districts, Oregon Science Teachers Association, Oregon Science Leaders, Regional STE(A)M Hub, Outdoor School Regional Coordinator, or Career Connected Learning Coordinators. Many of these educational networks have established partnerships to provide professional learning opportunities and can offer additional assistance.

Use these **reflection questions** independently or with your professional learning communities (PLC) to examine current instructional practices and to engage in future planning.

- How are the variety of cultures and perspectives viewed as an asset and support culturally responsive pedagogy?
- How are connections provided for students to ensure linguistic and cultural diversity is facilitated during learning?
- How are students provided connections to understand the relevance and importance to their daily lives, homes, neighborhoods, and communities?

Recognizing and supporting diversity in learning environments requires making diversity visible by thoughtfully considering the unique circumstances of each demographic group. This includes highlighting the knowledge and skills of individuals from diverse cultures, race, ethnicity, gender, class, ability, immigration history, gender identity, sexual identity, or some other dimension of difference, while showcasing their contributions and ways of knowing. One example of this approach is using place-based science education to connect learning to students' local context.

Equitable science learning environments must include activities that prioritize multiple ways of knowing, doing, and expressing understanding. This includes encouraging students to engage in meaningful and authentic ways. Some examples could be to anchor units with a justice-centered phenomena where they use science to develop ideas and solutions, and to authentic events—connecting science and society.

Supporting K-12 Science Instruction with High Quality Instructional Materials

High-quality instructional materials (HQIM) are critical to excellent instruction. A growing body of research points to the positive impact that high-quality instructional materials have on student learning.

In Oregon, science HQIM are basal instructional materials that include access to grade-level standards**, inclusive practices, support for teachers and students, and embedded assessments**. HQIM account for and honor the experiences of diverse learners, including educators, and their varying needs.

Use these **reflection questions** independently or with your professional learning communities (PLC) to examine current instructional practices and to engage in future planning.

- Who should be involved in the K-12 adoption of instructional materials and what tools are needed?
- What is an attainable, equity-driven vision for science instruction?
- What key shifts do we want to see in classrooms to support this vision?
- Do the instructional materials center student engagement on natural phenomenon and authentic problems? How are we making this engagement visible to students?
- Are there opportunities for ALL students to figure out phenomena or solve problems by using the three dimensions? If not, what supports are put in place to address this?

To fulfill the Division 22 Requirement for Instructional Materials, districts have the flexibility of two option to adopt instruction materials.

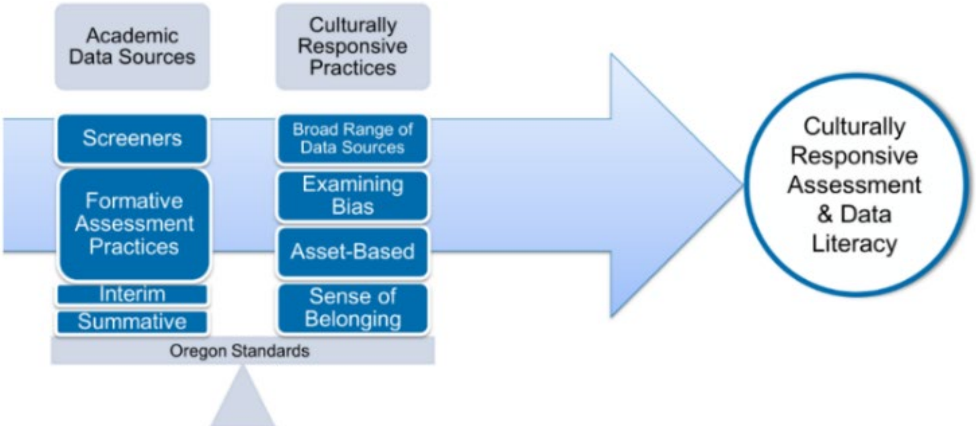
❖ **Option 1** - Adopt directly from the **Oregon State Board of Education's list** of approved K- 12 Science Instructional Materials.

❖ **Option 2** - Select materials that are **not on the ODE approved list** through an Independent Adoption, as outlined in OAR 581-022-2350, using the K-12 science adoption criteria for the content area under consideration.

A **district might choose Option 2** because not all potential K–12 science instructional materials undergo a formal review and evaluation by ODE. For instance, EdReports, a nonprofit organization that independently reviews instructional materials, and a collaborative Oregon team comprising of members from various ESDs and districts have independently reviewed and evaluated materials that may not appear on the Oregon- adopted list, such as Open Educational Resource (OER) materials. Additionally, districts might consider using cross-curricular units, especially in grades K–5, to **integrate standards across content areas and optimize learning time**.

Balanced Assessment System:
The Right Assessment for the Right Purpose

A world-class educational system needs to emphasize **assessment for learning**, such as formative assessment practices and appropriate use of interim assessment systems, more than **assessment of learning**, such as statewide summative assessments.



Culturally responsive practices are essential to a balanced assessment system, integrating multiple components beyond traditional academic data to identify growth opportunities and trends, supporting the design of equitable and effective instructional strategies for all students.

After establishing a classroom culture of learning, here are some science assessment considerations:

- ❖ Develop assessment maps to align the science curriculum with assessments, identifying gaps and overlaps within and across grade levels and content areas. It's crucial to critically **evaluate assessments and their intended outcomes to ensure they are effective and meaningful.**
- ❖ Provide students with **multiple opportunities and modalities** to showcase their science and engineering practices, cross-cutting concepts, and science content expertise thinking throughout the cycle of learning.
- ❖ Options to **gather evidence of learning** can include teacher observation, questioning, and noticing, laboratory experiences, projects, or interactive websites. The use of **detailed rubrics** or **observation tools** such as evidence statements, will assist students and educators in evaluating what **students should know and be able to do** by the end of instruction.

A **balanced assessment system** employs a variety of measures and types of assessment – Formative Assessment Practices, Interim and Summative Assessments. These equity-centered tools and resources help inform instructional decisions across the educational system.

Use these **reflection questions** independently or with your professional learning communities (PLC) to examine current instructional practices and to engage in future planning.

- How are current K-12 science assessments aligned with 3D learning and integrated into instruction to evaluate and support student thinking effectively?
- How do current classroom assessments provide a multifaceted view of students' knowledge and abilities, support diverse learners, and document progress over time?
- How are students actively engaged in setting goals and reflecting on their learning, while maintaining agency and ownership over their progress?
- Are assessment tools essential, effective, and practical for use by educators and students?

Additional Resources

Centering Student Engagement on Natural Phenomenon and Authentic Problems

K-12 Science Standards Learning Progressions: This document is designed to guide the progressive coherence of science instruction over time. It provides a structured pathway showing how students' thinking becomes increasingly sophisticated across each grade band.

Promote equitable sensemaking: This practice brief is designed to support instructional approaches that intentionally design collaborative discourse, build STEM identities, and create inclusive classrooms.

Phenomena in Science Instruction: This resource details the foundation of phenomena-driven instruction. It emphasizes the importance of centering K-12 science instruction on this approach and highlights its effectiveness.

Using Crosscutting Concepts to Engage Students: This document aims to support consistent and clear prompts structured around crosscutting concepts, providing a common scientific language for students and teachers to use during the formative assessment process.

Prompts for Integrating Crosscutting Concepts: This practice brief offers crosscutting concept prompts to help teachers elicit students' understanding of these concepts in the context of investigating phenomena or solving problems.

Equitable Student Engagement in Learning Science

Oregon Science Leaders Action Guide: This guide is intended to help Oregon school district leaders understand and address systemic challenges in K-12 science education.

ODE's Student Success Plans: These plans are designed to improve educational outcomes for students in Oregon, particularly those who the educational system has not adequately served.

Equity in K12 STEM Education Framing Decisions for the Future: This report puts forth a framework to guide decision makers short- and long-term goals for equity and to make decisions about STEM education policy and practice.

Culture, Learning and Identity Framework: This resource focuses on two major dimensions related to culture, learning, and identity: 1) issues of equity in science teaching and learning and 2) growing scientific knowledge and discovery itself.

Toward More Equitable Learning in Science: This chapter resource provides specific vignettes that illustrates culturally expansive perspective and opportunities for student engagement.

Culturally Responsive Teaching: A Reflection Guide: This report offers a set of reflection questions that help self-appraisal, goal setting, and critical conversations around culturally responsive teaching.

Supporting K-12 Science Instruction with High Quality Instructional Materials

WestEd Framework for Leading Next Generation Science Standards Implementation: This resource can be used as a self-assessment for leaders to identify areas for their further development to prepare them to lead standards implementation, and as a planning guide to help leaders think through the critical actions that they need to take for successful implementation.

NextGen Time Instructional Materials Implementation Guidelines: This suite of tools and process can provide guidance in evaluating the quality of instructional materials and alignment to the K-12 science standards.

Instruction Partners Curriculum Support Guide: This guide provides specific step with starter resources and notes to assist in avoiding common pitfalls.

Curriculum Implementation Change Framework: This resource facilitates strategic, responsive decision-making about how to support teachers and school-level leaders. It enables implementation leaders to deepen community-wide commitment to the curriculum and advance sustained student access to high-quality learning experiences.

Building Better PL: How to Strengthen Teacher Learning: This brief describes six key design features that recent evidence suggest are likely to improve classroom instructional practices and student outcomes.

Balanced Assessment System

NCSI Culturally Responsive Data Literacy: This document identifies the three pillars of culturally responsive data literacy and offers approaches for success.

A Tricky Balance: The Challenges and Opportunities of Balanced Systems of Assessment: This paper provides an in-depth analysis of factors that serve as barrier to the implementation of a balanced assessment system.

NGSS Assessment Portal: This resource provides sets of assessment tasks for 3-5 and 6-8 grade bands.

Stanford Assessment Project: This resource offers Short Performance Assessments (SPAs) designed to be taken individually at the end of a lesson sequence that addresses the grade level or grade band science standards.

STEM Teaching Tool on Using 3D Interim Assessments: This practice brief is designed to support the use of interim assessment to improve instructional or curriculum choices based on data analyzed at the classroom or school level.