INSTRUCTION PARTNERS

Solidify

Science Leadership Development Workbook

Introduction

Any scientist worth their name knows that it all starts with the questions:

What do we see?

What do we wonder?

How can we figure it out and make sense of it?

Throughout this leadership development series, you will ask (and attempt to answer) these questions as you solidify your knowledge about the current state of science instruction, dig into the wonder of science, and imagine the possibilities of what science education could be for each student in your classroom. As you complete these modules, you will build capacity to identify how to improve science education, and you will access practical tools that support describing, prioritizing, and planning for instructional growth in science.

Wondering:

What is an attainable and equity-driven vision for science instruction? What are the key shifts we want to see in classrooms?

The series begins by asking you—the leader—to establish your vision for science instruction. Before you move to describing your science education reality, let's firmly establish what you hope to see, hear, and experience when you walk into a science classroom.

Module aims:

- Outline and record initial ideas about what makes for excellent science teaching and learning
- Consider research that provides rationale for the instructional shifts that drove the creation of the NGSS
- Analyze teacher and student actions in two middle school classrooms to identify key shifts in science instruction and characteristics of those shifts

Introductory Task: What teacher and student actions are visible during excellent science instruction? (20 min)

To start, it's important to consider and record your initial thoughts about science teaching and learning in order to return to and strengthen, modify, or challenge them throughout the module.

- Complete the sentence and add your comment(s) on the "Initial Thoughts" collaborative board:

  Excellent science instruction is . . .

- Read the responses others have added to the board and consider what teacher and student actions would embody the noted definitions. List as many actions as you can think of in the chart below:

When excellent science teaching and learning is happening,

teachers are . . .	students are . . .

- Review your chart responses and **circle** the three most important actions on each side. Reflect: Why do you think these actions are so critical to science teaching and learning?

Task 1: Article dig—"What Science Teaching Looks Like: An International Perspective"[1] (45 min)

Building off of the actions you prioritized in the introductory task, this activity will allow you to dig into some of the research outlining teacher and student actions in high-performing science classrooms around the world.

- Use the following tracker to record key takeaways from the article's description of science instruction in each country on pages 1–4:

	Notes from Article
Czech Republic	
Japan	
Australia	
The Netherlands	
United States	

[1] ASCD. "What Science Teaching Looks like: An International Perspective." Ascd.org. Accessed February 19, 2021. http://www.ascd.org/publications/educational-leadership/deco6/vol64/numo4/What-Science-Teaching-Looks-Like@-An-International-Perspective.aspx.

- What is an initial takeaway you have after reading through the description of science instruction in each country?

- Consider *Figure 1. To what degree do science lessons focus on concepts?* How did the United States compare to high-performing countries in the conceptual focus of lessons?

- The article's authors recommended four directions for improving science teaching in the United States:

  1. Develop a clear, coherent science content storyline
  2. Link all activities to science ideas
  3. Strengthen teachers' content knowledge
  4. Rethink the role of content in science teaching

Consider each of these recommendations on pages 5–6 of the article and think back to your chart from the introductory activity. **What things would you change, add, and remove from your actions list?**

Change	
Add	
Remove	

- The NGSS (and many state standards that are similar in structure and research base) require several conceptual shifts that impact teaching and learning in the science classroom. The seven conceptual shifts outlined by the NGSS are:[2]

  - **K-12 science education should reflect the real world interconnected nature of science as it is practiced and experienced in the real world.**
  - The Next Generation Science Standards are student performance expectations—NOT curriculum.
  - **The science concepts in the NGSS build coherently from K–12.**
  - **The NGSS focus on deeper understanding of content as well as application of content.**
  - Science and engineering are integrated in the NGSS, from K-12.
  - **The NGSS are designed to prepare students for college, career, and citizenship.**
  - The NGSS and Common Core Standards (ELA and Math) are aligned.

Understanding these highlighted shifts will guide much of our work throughout this series; however, all seven are important to consider. You can read about each in more detail in Appendix A of the NGSS.

Reflect: **What connections do you see between the research article and those bolded conceptual shifts present in the NGSS?**

[2] Nextgenscience.org. "Appendix A - Conceptual Shifts in the Next Generation Science Standards." Accessed February 19, 2021. https://www.nextgenscience.org/sites/default/files/Appendix%20A%20-%20 4.11.13%20Conceptual%20Shifts%20in%20the%20Next%20Generation%20Science%20Standards.pdf.

Task 2: The shifts in action—a tale of two classrooms (60 min)

Now that you've explored some characteristics of good science instruction and have been introduced to the rationale behind the conceptual shifts of the NGSS, it's time to consider these ideas through the lens of a classroom (or two!).

Meet Mr. Cole and Ms. Rivera. They both teach at the same middle school and are starting a new life science unit on interdependent relationships in ecosystems.

- Read lessons 1–3 of Mr. Cole's unit.[3] Last the teacher and student actions by lesson in the chart below as you read.

	Teacher Actions	Student Actions
Lesson 1		
Lesson 2		
Lesson 3		

- Read lessons 1–3 of Ms. Rivera's unit.[3] List the teacher and student actions by lesson in the chart below as you read.

[3] Amnh.org. "Tool 3: Using the 5E Instructional Model to Develop a Conceptual Flow." Accessed May 14, 2021. https://www.amnh.org/learn-teach/curriculum-collections/five-tools-and-processes-for-ngss/tool-3.

	Teacher Actions	Student Actions
Lesson 1		
Lesson 2		
Lesson 3		

- Reflect on the lessons, and list the similarities and differences you observed between them.

- Consider the article you read and conceptual shifts you reviewed in Task 1 of this module. In addition, browse this summary of implications for science education.[4] How does each teacher's instruction compare to the ideas around which we want to refocus science education?

[4] NSTA. "NGSS Hub." NGSS@NSTA, ngss.nsta.org/about.aspx. Accessed 24 May 2021.

- Revisit your list of teacher and student actions that are visible during excellent science instruction again.

Change	
Add	
Remove	

Reflect: As a leader, what actions would you need to take to support the teacher and student actions you've highlighted?

Bridge to Practice

The bridge to practice supports leaders in translating module learning into practical and accessible professional learning opportunities for other science educators. For Module 1, how can you support others in establishing a vision for science instruction that encompasses the key shifts championed by the NGSS? The resources below can be used to plan and execute that learning within a two-part PLC series:

- Conceptualizing A Vision for Science Teaching and Learning: Part 1
  - Session outline
  - Session starter deck
  - Session handouts

- Conceptualizing A Vision for Science Teaching and Learning: Part 2
  - Session outline
  - Session starter deck
  - Session handouts

Wondering:
What is the role of phenomena in our vision for science education?

In Module 1, we explored the rationale of the instructional shifts behind the NGSS and highlighted characteristics of science classrooms that embrace these shifts. One of those characteristics was shifting from instruction structured around the teacher providing information about a science topic to students asking questions and digging deeper to figure out the "why" or "how" of an observable event (i.e., a phenomenon). Now, you will explore the use of phenomena in science education to facilitate that shift and support providing access to content for all students.

Module aims:

- Articulate the benefits of using phenomena as the driver of instruction in science and to provide equitable access to learning opportunities
- Analyze the storyline of a high-quality instructional unit to explore how students progressively build understanding of science ideas through engagement with phenomena

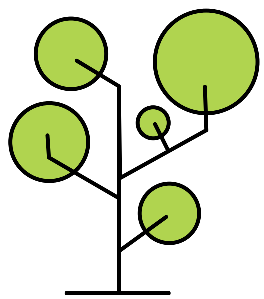
Introductory Task: A "Phenomenal" Anchor (20 min)

Let's jump in with some science questions of our own!

- Answer the following question without accessing references or using anything other than your own existing knowledge:

  Where does a plant's mass come from?

  This large tree started as a little seed. What provided most of the mass that made the tree grow so large?[5]



- I think most of it came from nutrients in the soil that are taken up by the plant's roots.
- I think most of it came from the sun's energy.
- I think most of it came from molecules in the air that came in through holes in the plant's leaves.
- I think most of it came from the water taken up directly by the plant's roots.

[5] Koba, S., & Tweed, A. (2009). Hard-To-Teach Biology Concepts: A Framework to Deepen Student Understanding. National ScienceTeachers Association.

Which answer do you most agree with and why?

- Watch this video[6] to explore how college graduates answered this question, find out the correct answer, and consider what impacted your thinking as you chose your answer.

- How did you do? How might we go about preparing our students to construct deeper meaning, develop conceptual understanding, and be scientifically literate? Jot down your initial thoughts here:

[6] Photosynthesis at MIT." YouTube, uploaded by Stephen Rowcliffe, 28 Apr. 2015, www.youtube.com/watch?v=JhCHb6xtqeY.

Task 1: Article dig —"Using Phenomena in NGSS" (30 min)

The power of deepening understanding of science content through the process of figuring out the world around you is a key idea underlying best practices for planning science instruction. This task will allow space for exploring how phenomena can be used in implementing the NGSS and other science standards.

- Use the following tracker to record key takeaways from the article:[7]

	Notes from Articles
What are phenomena?	
How do phenomena relate to science teaching and learning?	
What makes the use of phenomena to drive instruction so effective?	
How does the use of phenomena in instruction relate to providing equitable science education for all students?	

[7] Nextgenscience.org. "Using Phenomena in NGSS-Designed Lessons and Units." Accessed November 17, 2020. https://www.nextgenscience.org/sites/default/files/Using%20Phenomena%20in%20NGSS.pdf

How should our thinking about phenomena shift as we implement science standards?

- What is the most important idea that surfaces for you after reading the article?

- As we mentioned in Module 1, the NGSS (and many state standards that are similar in structure and research base) require several conceptual shifts that impact teaching and learning in the science classroom. The four conceptual shifts that this series focuses on are:
  - K–12 science education should reflect the real world interconnected nature of science as it is practiced and experienced in the real world.
  - The science concepts in the NGSS build coherently from K to 12.
  - The NGSS focuses on deeper understanding of content as well as application of content.
  - The NGSS are designed to prepare students for college, career, and citizenship.

Reflect: **What connections do you see between the phenomena article and any of the focus conceptual shifts listed above?**

Task 2: The shifts in action—phenomena-driven instruction (30 min)

Now that you've expored the big ideas around phenomena-driven instruction and the beneficial impact it can have on providing equitable educational opportunities, it's time to consider what this can look like in action.

Meet M'Kenna. She is a 13-year-old girl who is really sick, but we have no idea why. M'Kenna's story drives the OpenSciEd unit called "Metabolic Reactions" which we'll explore today using this Unit Storyline.[8]

- Take a moment to read the information shared in lesson 1 of the unit.
  - What seems to be the purpose of this lesson within the unit?

  - The phenomena presented in the lesson (M'Kenna's Doctor's Note) is meant to be observable for students. Why do you think this is important?

[8] OpenSciEd. "What Is Going on inside M'Kenna's Body That Is Making Her Feel the Way She Does?" Openscied.org. Accessed June 7, 2020. https://www.openscied.org/wp-content/uploads/2020/07/Metabolic-Reactions-Storyline.pdf.

    - What did students figure out in this lesson? Can they explain what's going on with M'Kenna at this point?

    - What science ideas might students need to learn in order to fully explain what's going on with M'Kenna? Be as general or specific as you'd like.

- Take time to read lessons 2–4 of the "Metabolic Reactions" unit. Focus on the "Navigation to Next Lesson" section after each row.
    - What is the story of the unit so far?

    - What do you notice about how students engage with the anchoring phenomenon over these lessons (what's wrong with M'Kenna)?

Reflect: **What connections do you see between the way this unit of instruction uses phenomena and any of the focus conceptual shifts listed above?**

- Look back at the four conceptual shifts that this series focuses on:
  - K–12 science education should reflect the real world interconnected nature of science as it is practiced and experienced in the real world.
  - The science concepts in the NGSS build coherently from K to 12.
  - The NGSS focuses on deeper understanding of content as well as application of content.
  - The NGSS are designed to prepare students for college, career, and citizenship.

Bridge to Practice

The bridge to practice supports leaders in translating module learning into practical and accessible professional learning opportunities for other science educators. For Module 2, how can you support others in understanding how phenomena-driven instruction supports the conceptual shifts in science instruction the NGSS champion? The resources below can be used to plan and execute that learning within a PLC series:

- Phenomena-Driven Instruction
  - Session outline
  - Session starter deck
  - Session handouts

Wondering:
What are the three dimensions and what is their role in science instruction?

Phenomena drive instruction and provide students with an anchor that is observable, and shift learning to "figuring out" the natural and engineered world. But, what does instruction have to look like in order for students to deepen their understanding of science in a way that allows for explanation of phenomena? In this module, we will explore the three dimensions encompassed in the NGSS and quality science instruction.

Module aims:

- Identify and define each of the three dimensions—Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts—that make up the NGSS and other K–12 Framework-based standards.
- Analyze a high-quality instructional unit to explore how the three dimensions come alive within instruction and support engaging with phenomena

Introductory Task: Three-dimensional instruction (20 min)

- What do you currently know and understand about three-dimensional instruction? Do you have any specific questions that come up when considering the term? Jot down your answers here:

- Watch this video that introduces the idea of three-dimensional instruction.[9] What strikes you and what question(s) does it surface?

[9] WebsEdge Science. "Three-Dimensional Instruction." Accessed May 27, 2021. https://www.youtube.com/watch?v=1g9CUY1TBS8.

Task 1: The shifts in action—disciplinary core ideas (20 min)

You may have heard that the newest science standards are three dimensional, but what does that mean and how does it impact instruction? Let's use the same "Metabolic Reactions" unit to explore what each of the three dimensions bring to coherent science instruction.

Dimension 1: Disciplinary Core Ideas (DCIs) are "the fundamental ideas that are necessary for understanding a given science discipline."[10] They are key to understanding complex ideas and are taught across grade bands as they progressively deepen in complexity. They include:[11]

Science Disciplines	Disciplinary Core Ideas (DCIs)
Physical Science (PS)	PS1: Matter & Its Interactions / PS2: Motion & Stability PS3: Energy / PS4: Waves & Their Applications
Life Science (LS)	LS1: From Molecules to Organisms / LS2: Ecosystems LS3: Heredity / LS4: Biological Change
Earth and Space Science (ESS)	ESS1: Earth's Place in the Universe / ESS2: Earth's Systems ESS3: Earth & Human Activity
Engineering, Technology and Application of Science (ETS)	ETS1: Engineering Design ETS2: Links Among Engineering, Technology, Science and Society

In short, the Disciplinary Core Ideas and their elements encompass the key science ideas students need to understand in order to explain phenomena and design solutions.

[10] Nextgenscience.org. "Disciplinary Core Idea (DCI)." Accessed May 14, 2021. https://www.nextgenscience.org/glossary/disciplinary-core-idea-dci.

[11] Board on Science Education, Division of Behavioral and Social Sciences and Education, Committee on Conceptual Framework for the New K-12 Science Education Standards, and National Research Council. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Edited by Helen Quinn, Heidi A. Schweingruber, and Thomas Keller. Washington, D.C., DC: National Academies Press, 2012.

- Read through the remainder of the Unit Storyline and keep track of the key science ideas that students figure out over time in the chart below. **Hint:** Focus on the "What we do and figure out" section.

	Key Science Ideas
Lessons 1–4	
Lessons 5–8	
Lessons 9–12	
Lessons 13–15	

- OpenSciEd identifies that student understanding of these grade 6–8 DCI elements is expanded during the "Metabolic Reactions" unit:[12]

    - **LS1.A Structure and Function:** In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.
    - **LS1.B Growth and Development of Organisms:** The growth of an animal is controlled by food intake.
    - **LS1.C Organization for Matter and Energy Flow in Organisms:** Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.
    - **PS3.D Energy in Processes and Everyday Life:** Cellular respiration in animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

Choose one DCI element to compare to your list of key science ideas from the unit. What science ideas did students learn within throughout the unit that built understanding of your chosen DCI element?

[12] OpenSciEd. "What Is Going on inside M'Kenna's Body That Is Making Her Feel the Way She Does?" Openscied.org. Accessed June 7, 2020. https://openscied-uploads-production.s3.amazonaws.com/G7_UMR/lowres/7.3%20Metabolic%20Reactions%20Teacher%20Edition.pdf

Task 2: The shifts in action—science and engineering practice (20 min)

Dimension 2: Science and Engineering Practices are "what students DO to make sense of phenomena."[13] These are eight practices that scientists and engineers use to investigate the world and are a set of skills and knowledge that are to be internalized progressively over the K–12 education experience. The eight practices are:[14]

Practices for K–12 Science Classrooms

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

[13] Nextgenscience.org. "Science and Engineering Practices (SEP)." Accessed May 14, 2021. https://www.nextgenscience.org/glossary/science-and-engineering-practices-sep.

[14] Board on Science Education, Division of Behavioral and Social Sciences and Education, Committee on Conceptual Framework for the New K-12 Science Education Standards, and National Research Council. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Edited by Helen Quinn, Heidi A. Schweingruber, and Thomas Keller. Washington, D.C., DC: National Academies Press, 2012.

- Go back to the Unit Storyline and focus on the "What we do and figure out" section of each lesson summary. What science and engineering practices (SEPs) do you see students engage in throughout this unit? In the table below, jot down at least three and the specific example you saw:

	Science and Engineering Practice Identified	Example from Unit Storyline
Example:	*Planning and Carrying Out Investigations*	*In Lesson 3, students investigate whether food particles can pass through a surface similar to the small intestine.*
1		
2		
3		

- Check your answers using this document that outlines the SEP elements students engage in during each lesson.[15] How do the Science and Engineering Practices seem related to the Disciplinary Core Ideas students are figuring out?

[15] OpenSciEd. "What Is Going on inside M'Kenna's Body That Is Making Her Feel the Way She Does?" Openscied.org. Accessed June 7, 2020. https://drive.google.com/drive/folders/1Epw5QYy9HBDNYoMBN4DCYCuLwj1u8Tbi

Task 3: The shifts in action—crosscutting concepts and closing (20 min)

Dimension 3: Crosscutting Concepts (CCCs) are "concepts that hold true across the natural and engineered world."[16] They are used by students to make connections across disciplines, situations, and new learning. They are also used to make sense of phenomena and solve problems. The seven CCCs are:[17]

Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Cause and Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

[16] Nextgenscience.org. "Crosscutting Concepts (CCC)." Accessed May 14, 2021. https://www.nextgenscience.org/glossary/crosscutting-concepts-ccc.
[17] Nextgenscience.org. "Appendix G - Crosscutting Concepts" Accessed February 19, 2021. https://www. nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Energy and Matter

Tracking energy and matter flows, into, out of, and within systems helps one understand their system’s behavior.

Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand

- The "Metabolic Reactions" unit identifies two focal CCCs: Structure and Function and System and System Models. Considering the chart above and what you now know about the unit, why would students need to understand these two concepts in order to fully explain what happened to M’Kenna? Refer to the CCC elements outlined in this document to check your thinking.[18]

[18] OpenSciEd. “What Is Going on inside M’Kenna’s Body That Is Making Her Feel the Way She Does?” Openscied.org. Accessed June 7, 2020. https://drive.google.com/drive/folders/1Epw5QYy9HBDNYoMBN4DCYCuLwj1u8Tbi

- Consider the video you watched during the introduction and look back at the four conceptual shifts that this series focuses on:
  - K–12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.
  - The science concepts in the NGSS build coherently from K to 12.
  - The NGSS focus on deeper understanding of content as well as application of content.
  - The NGSS are designed to prepare students for college, career, and citizenship.

Reflect: **What connections do you see between three-dimensional instruction and any of the focus conceptual shifts listed above? Jot down your thoughts here:**

- Consider how three-dimensional instruction supports students' access to content. How is this relevant to a push for more equitable science education opportunities for all students?

Bridge to Practice

The bridge to practice supports leaders in translating module learning into practical and accessible professional learning opportunities for other science educators. For Module 3, how can you support others in understanding how three-dimensional instruction supports the conceptual shifts in science instruction that the NGSS champion? The resources below can be used to plan and execute that learning within a PLC series:

- Three-Dimensional Instruction
  - Session outline
  - Session starter deck
  - Session handouts