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Next Generation Science Standards in Practice

Tools and Processes Used by the California NGSS Early Implementers

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NGSS EARLY IMPLEMENTERS
WestEd

NGSS Early Implementers Initiative: Bringing science to life as a core subject in K–8 classrooms

A diverse group of eight California school districts and two charter management organizations is actively implementing the Next Generation Science Standards (NGSS). Their progress, experiences, and lessons can inform others implementing the NGSS. The NGSS Early Implementers are supported by the K–12 Alliance at WestEd, and work in partnership with the California Department of Education, the California State Board of Education, and Achieve. Initiative funding is provided by the S. D. Bechtel, Jr. Foundation, with the Hastings/Quillin Fund supporting participation by the charter organizations.

The Initiative spans 2014 to 2020. It focuses on NGSS implementation in grades K–8 and incorporates the integrated course model (preferred by the California State Board of Education) for middle school.

Teachers are supported with strategies and tools, including an instructional framework that incorporates phenomena-based learning. This framework aligns with the NGSS three dimensions: disciplinary core ideas, crosscutting concepts, and science and engineering practices. Using science notebooks, questioning strategies, and other approaches, students conduct investigations, construct arguments, analyze text, practice descriptive skills, articulate ideas, and assess their own understanding.

Teachers engage in science lesson studies twice each year through a Teaching Learning Collaborative. In each district, the Initiative is guided by a Core Leadership Team of Teacher Leaders and administrators who participate in additional professional learning and coaching activities. Together, this core team and an extended group of Teacher Leaders are the means for scaling NGSS implementation throughout the district.

Learn more about this multi-year initiative and access evaluation findings as well as instructional resources at k12alliance.org/ca-ngss.php.

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Evaluation of the NGSS Early Implementers Initiative

The S. D. Bechtel, Jr. Foundation commissions WestEd's STEM Evaluation Unit to independently evaluate the NGSS Early Implementers Initiative in the eight participating public school districts. As part of that evaluation, the team is releasing a series of evaluation reports (as described in the Evaluation Report Series subsection below).

However, this current publication is a special report outside of that evaluation report series. To produce this special report, which is more descriptive than evaluative, the evaluators and leaders of the Early Implementers Initiative collaborated to jointly present a collection of tools and processes used by Early Implementers during the first four years of the Initiative. Co-authors from the Early Implementers Initiative include K–12 Alliance Regional Directors and district Project Directors. Regional and Project Directors together plan and implement the project-wide professional learning and other activities of the Early Implementers Initiative.

Evaluation Report Series

Evaluators of the Early Implementers Initiative collect and analyze data independent of Initiative leaders and previously have released four evaluation reports of findings:

Moving the Needle (Report #1, October 2016), which describes the Initiative's early progress on three implementation goals: integrating science and ELA, integrating the sciences in middle school, and making science a core school subject.

The Synergy of Science and English Language Arts (Report #2, October 2017), which updates and expands the topic of integrating science and ELA, including describing what such integration can look like in the classroom.

Administrators Matter in NGSS Implementation: How School and District Leaders are Making Science Happen (Report #3, November 2017), which describes how administrators are advancing NGSS implementation in their schools and districts, how teachers are benefitting from administrators' support, and how the Initiative is empowering administrators' efforts.

Developing District Plans for NGSS Implementation: Preventing Detours and Finding Express Lanes on the Journey to Implement the New Standards (Report #4, February 2018), which describes the process, benefits, and challenges of developing a detailed, long-range district plan for implementing the NGSS.

Evaluators plan reports on these additional topics during 2018:

- Describing middle school science integration in the classroom
- Teacher leadership in the NGSS Early Implementers Initiative
- The impacts of NGSS implementation for students

Introduction

The aim of the NGSS Early Implementers Initiative is not only to be in the vanguard of Next Generation Science Standards implementation in California, but also to provide other districts with practices and guidance that may benefit their implementation efforts. Accordingly, this report describes the key tools and processes that NGSS Early Implementers are using to implement Next Generation Science Standards instruction.

Specifically, this report focuses on the tools and processes[1] that have been a central part of the professional development provided to teachers and administrators during the first four years of the Initiative. The report is not intended to be a "how-to" manual. Rather, it presents items that other districts and schools can learn from, draw upon, and adapt to support NGSS implementation in their contexts.

The tools and processes are organized into three main sections to help readers easily find entries of particular interest to them:

- NGSS lesson planning
- NGSS instruction
- Administrator support of NGSS implementation

WHO wrote this report?

All other NGSS Early Implementers Initiative evaluation reports are authored by the evaluation team members and based primarily on evaluation data they collect about the Initiative's NGSS implementation. The goal of this particular report was not to evaluate the Initiative, but to work with the Initiative's leaders to share information with the field about key tools and processes that are benefitting districts in their NGSS implementation in various ways. Evaluators collaborated with staff from the K–12 Alliance and district Project Directors, who are leading the Initiative, to write descriptions of the tools and processes being used to help participating districts implement the NGSS. Evaluators also added data from the evaluation (e.g., data on changes in usage of tools over the course of the Initiative; comments about tools that were expressed by project participants during observations, interviews, and surveys).

WHO developed these tools and processes?

Some tools and processes were developed specifically by and for the Early Implementers Initiative. Others have been used by the K–12 Alliance for many years as vehicles for empowering the kinds of effective science teaching and learning that are recommended by research. Most of those pre-existing items were adapted by the Initiative's leadership to be used explicitly for the purpose of supporting NGSS implementation. In other instances, the K–12 Alliance adapted well-regarded tools from other sources. In these cases, the report gives attribution to the items' sources.[2]

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[1] We use the words "tool" and "process" as umbrella terms to cover a range of items being described in this report (e.g., resources, protocols, strategies, practices).

[2] Appendix A also provides a list of related publications from other sources.

WHEN did the Initiative equip Teacher Leaders and administrators to use these tools and processes?

Many tools and processes have been used by participants in all of the Early Implementer districts since the beginning of the Initiative.[3] For example, several of the tools and processes for empowering teachers' science lesson planning and instruction have been used throughout the Initiative in its primary professional learning sessions. These sessions include annual, week-long summer institutes for all Teacher Leaders; semi-annual, multi-day sessions for Core Leadership Team members; and twice-yearly, two-day Teaching Learning Collaboratives (TLCs, or "lesson studies") wherein teams of Teacher Leaders create and teach NGSS-aligned lessons.

Other tools and processes were introduced more recently — Initiative efforts to involve administrators have increased each year — so new ones are being created over time for this effort.

WHO are the participants in the NGSS Early Implementers Initiative?

This report's descriptions of tools and processes often reference key participants who helped to develop them, have used them, and/or have provided feedback to evaluators about their value. Following is a summary description of these Early Implementer participants:

- NGSS implementation in each district has been planned and coordinated by a **Core Leadership Team** consisting of:
    - Three to five **Core Administrators**, who may work at the district or school level
    - Five to ten **Core Teacher Leaders** representing a range of grade levels and schools throughout the district
- A district **Project Director** leads the Core Leadership Team and oversees the NGSS implementation activities in the district.
- A designated **Regional Director** from WestEd's K–12 Alliance provides support and professional learning to each district Core Leadership Team.
- **Teacher Leaders** (30–70 per district) were recruited at the beginning of year 2 of the Initiative to receive professional learning in NGSS and leadership. They are now playing an instrumental role in spreading NGSS expertise to other teachers in the district.

Descriptions of participants can also be found in the *Glossary*.

HOW are the tools and processes organized in this report?

As listed below, the tools and processes in this report are grouped by how participants in the Initiative use them.

Tools and processes that empower NGSS lesson planning:

- Criteria for Choosing Phenomena

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[3] A separate evaluation report (#2) describes some tools and processes that Initiative participants have used specifically for creating a Synergy of Science and English Language Arts. See https://www.wested.org/resources/synergy-of-science-and-english-language-arts/

- Phenomena-Based, Three-Dimensional Conceptual Flow
- "5E" Instructional Model for Developing Learning Sequences
- Teaching Learning Collaborative (TLC)

Tools and processes that empower NGSS instruction:

- Looking at Student Work
- Questioning Strategies that Promote Student Discourse
- Sense-Making Student Notebooks

Tools and processes that empower administrator support of NGSS implementation:

- Principal Academy
- Walk-Through Protocol
- Evidence of Learning Protocol

For each tool/process, we describe what it is and how participants in the Initiative have been using it, and we share data from the evaluation team's observations, surveys, and interviews on how participating teachers and administrators are benefitting from it.

Although each item is placed in only one of the three categories above in this report, we acknowledge that many can be applied in both planning and delivering instruction. However, each tool's role is typically more pertinent to carrying out one function over the other. For example, items grouped under empowering NGSS instruction primarily serve that role, but they often are addressed during lesson planning as well — that is, planning often includes discussion of when and how to use these teaching tools and processes during instruction.

A few items, particularly the Teaching Learning Collaborative (TLC, or "lesson study"), serve strongly in both the planning and instruction functions. The description of the TLC explains that teachers convene for a planning day and subsequently meet again to teach the planned lesson; however, we've placed the TLC entry in its first occurrence in the list, which is for planning instruction.

Empowering NGSS Lesson Planning

This section describes the following Initiative tools and processes used in teachers' NGSS lesson planning:

- Criteria for Choosing Phenomena
- Phenomena-Based, Three-Dimensional Conceptual Flow
- "5E" Instructional Model for Developing Learning Sequences
- Teaching Learning Collaborative (TLC)

The process of lesson planning as conducted by the Early Implementers Initiative begins with the selection of an appropriate phenomenon upon which to base an extended instructional unit, continues to the mapping out of a conceptual flow "storyline" for that unit, and culminates in the development of a detailed "5E" learning sequence plan.

The final item in this section, *Teaching Learning Collaborative* (TLC), describes how teams of teachers meet to plan instruction. Those planning sessions regularly involve the use of the other items described in this section: *criteria for choosing phenomena*; *phenomena-based, three-dimensional (3D) conceptual flow*; and *"5E" instructional model*.

Criteria for Choosing Phenomena

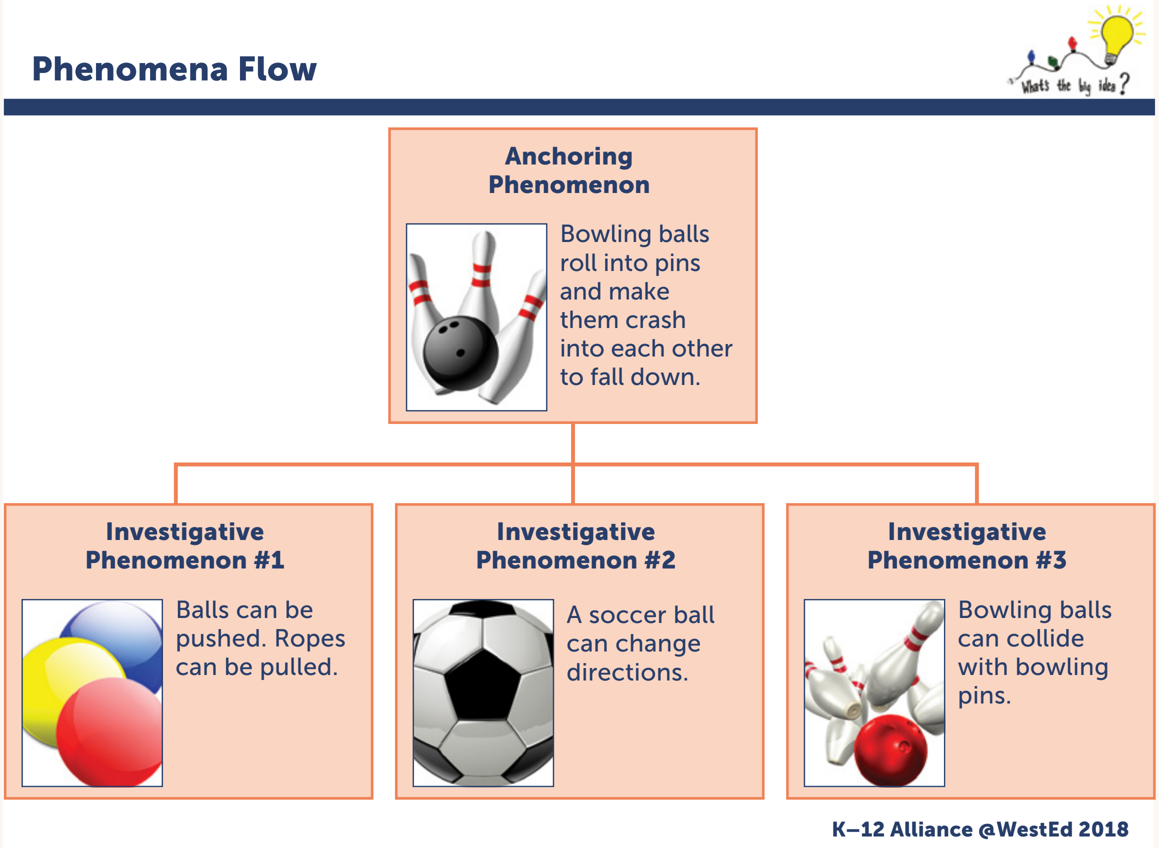
For too long science instruction has mostly or only emphasized transmitting knowledge to students in a passive, disconnected way. Students often would moan, "Why do I need to learn this?" and struggle to find meaning in what they were asked to do. The NGSS has shifted instruction away from that approach, toward a more active, inquiry-based, sense-making experience for students. Through NGSS-aligned instruction, students are presented with naturally occurring phenomena, ideally with local relevance that they see playing out in their lives, chosen explicitly to both match target learning outcomes and spark their curiosity. The focus of instruction is then on students "figuring out" solutions to problems, answers to questions, or scientific explanations related to the phenomena. One key for this deep scientific learning is choosing appropriate phenomena for engaging students and driving the instruction.

In this section, we first define and describe what the term "phenomena" means in the context of the NGSS; we then describe the criteria that the Initiative uses to help instructors choose appropriate phenomena for their NGSS-aligned instruction.

Defining Phenomena

The Early Implementers Initiative defines phenomena as "occurrences in the natural and human-made world that can be observed and cause one to wonder and ask questions." Focusing instruction on phenomena "requires students to use the science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs) in concert to explore, investigate, and explain how and why phenomena occur" (Brown et al., n.d.). The NGSS do not specify which

Figure 1. Example of the flow of anchoring and investigative phenomena in a unit of study



Phenomena Flow

Anchoring Phenomenon

Bowling balls roll into pins and make them crash into each other to fall down.

Investigative Phenomenon #1

Balls can be pushed. Ropes can be pulled.

Investigative Phenomenon #2

A soccer ball can change directions.

Investigative Phenomenon #3

Bowling balls can collide with bowling pins.

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phenomena to use in science instruction, "because phenomena need to be relevant to the students that live in each community and should flow in an authentic manner" (California Department of Education, 2016). Instead, teachers are encouraged to select phenomena that will engage *their* students, taking into consideration the local context as well as student ability levels, interests, and previous experiences.

There are two main types of phenomena that can be used in science instruction: **anchoring** phenomena and **investigative** phenomena. These two categories describe the scale or size of the phenomenon — that is, "the length of instructional time required to teach it, the depth of student explanation possible, and the complexity of the phenomenon itself" (Brown et al., n.d.).

- Anchoring phenomena are larger in scale and are the focus of instructional units (i.e., instruction over multiple weeks). They connect to the smaller, investigative phenomena that occur at multiple points throughout that unit of instruction (see Figure 1).
- The investigative phenomena serve as the foci of learning sequences (i.e., instruction over multiple days), and help students develop understanding of scientific concepts related to the larger anchoring phenomenon. Brown and colleagues (n.d.) explain, "by having students observe and explain smaller related phenomena first, they can then be challenged

to explain the larger and more complicated phenomena."

Criteria for Selecting Useful Phenomena

The Early Implementers Initiative uses the following guiding questions and criteria to help instructors choose appropriate phenomena:[4,5]

- Can students **observe** and/or **investigate** the phenomenon either through firsthand experiences (e.g., directly in a classroom, lab, or outdoor environment) or through someone else's experiences (e.g., through video presentations, demonstrations, or analyzing patterns in data)?
- Do students have to understand and use **science and engineering practices**, **disciplinary core ideas**, and **crosscutting concepts** to explain how and why the phenomenon occurs?
- By making sense of the phenomenon, are students building understanding toward grade-level **performance expectation(s)**?
- Would student explanations of the phenomenon be **grade-level appropriate**?
- Is the phenomenon **relevant** to real-world issues or the students' local environment?
- Will students find making sense of the phenomenon **interesting** and **important**?
- Does the potential student learning related to the phenomenon justify the **financial costs** and **classroom time** that will be used? (Brown et al., n.d.)

Early Implementers' Reaction

Early Implementer teachers have increased their use of phenomena to frame science instruction over the course of the Initiative. While only 17 percent of surveyed teachers in 2015–16 reported using phenomena at least weekly, that figure more than doubled to 36 percent the following year. Similarly, the percentage of teachers who reported using phenomena less than four times all year fell from 36 percent in 2015–16 to 17 percent in 2016–17.

The following quotes from two Early Implementer teachers illustrate the value that many of the Initiative's teachers have placed on using phenomena in instructional design and delivery:

> *As an educator we want our students to be engaged in each and every lesson. When students are learning new science content, it is imperative that they are able to have real world application for it. When looking at the standards, we are able to look for phenomenon that will pique students' interests and spark questioning and critical thinking skills. The students from last year still talk about one experiment, and their knowledge of the properties of matter is unparalleled! It was a true trifecta: fun, learning, and critical thinking! — Grade 2 teacher*

> *We really spend time working on asking questions, especially as it relates to the phenomena and then coming back and seeing if they're answering their own questions. I do find that the way that my kids are reacting is that I do get more*

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[4] See Appendix B for the full Early Implementer tool, Criteria for Selecting Useful Phenomena (Brown et al., n.d.) developed in collaboration with #ProjectPhenomena, San Diego County Office of Education. https://sites.google.com/site/sciencephenomena/criteria

[5] See Appendix C for Early Implementer phenomena ideas by grade level (K–8).

> *quality questions that are coming out of them, and really probing, and I can tell that they're thinking more deeply about what we're studying than they did in the past. — Grade 8 Teacher Leader*

Phenomena-Based, 3D Conceptual Flow

The conceptual flow is a process for graphically mapping the storyline of a three-dimensional (3D) NGSS instructional unit lasting six to eight weeks or longer.[6] A 3D unit addresses, in an integrated way, each of the three dimensions of the NGSS: science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs).[7]

Designed to be collaboratively carried out by a team of same grade-level teachers, the process of developing a conceptual flow consists of five basic steps:

1. Identify an anchor phenomenon for an instructional unit.
2. Conduct a "pre-think" of the important concepts students should understand in order to explain the anchor phenomenon (this step is carried out individually).
3. Create a collaborative "cluster map" from the individual pre-thinks on a large poster.
4. Match SEPs, DCIs, and CCCs to the collaborative cluster map and make sure these match the NGSS for the target grade level.
5. Create a conceptual flow graphic by placing the concepts in a coherent instructional sequence for building student understanding.

Constructing the conceptual flow is about more than developing an instructional unit. It is a springboard for teachers' conversations about teaching and learning. Although a conceptual flow can be developed by an individual teacher, it is much better done as a collaborative process through conversation with colleagues. All phases of the process allow for rich conversations as teachers negotiate and share ideas, grapple with content, consider sequencing, and begin to formulate potential student activities. Of particular note is that in both elementary and middle school, teachers recognize the natural connections between science disciplines (e.g., engineering, life, physical, earth/space science) that arise as part of developing a flow around an anchoring phenomenon. Rarely will a conceptual flow be made up of solely one science discipline, as one can rarely fully explain a phenomenon with only one science discipline.

The resulting conceptual flow graphic is a reference for teachers as they plan instruction of the learning sequences that make up the overall instructional unit. It provides the big ideas that are important for students to know, the standards they are responsible for teaching, and the target SEPs, DCIs, and CCCs in one comprehensive, sequential representation. Figure 2 shows an example of a completed conceptual flow from the 5th grade.

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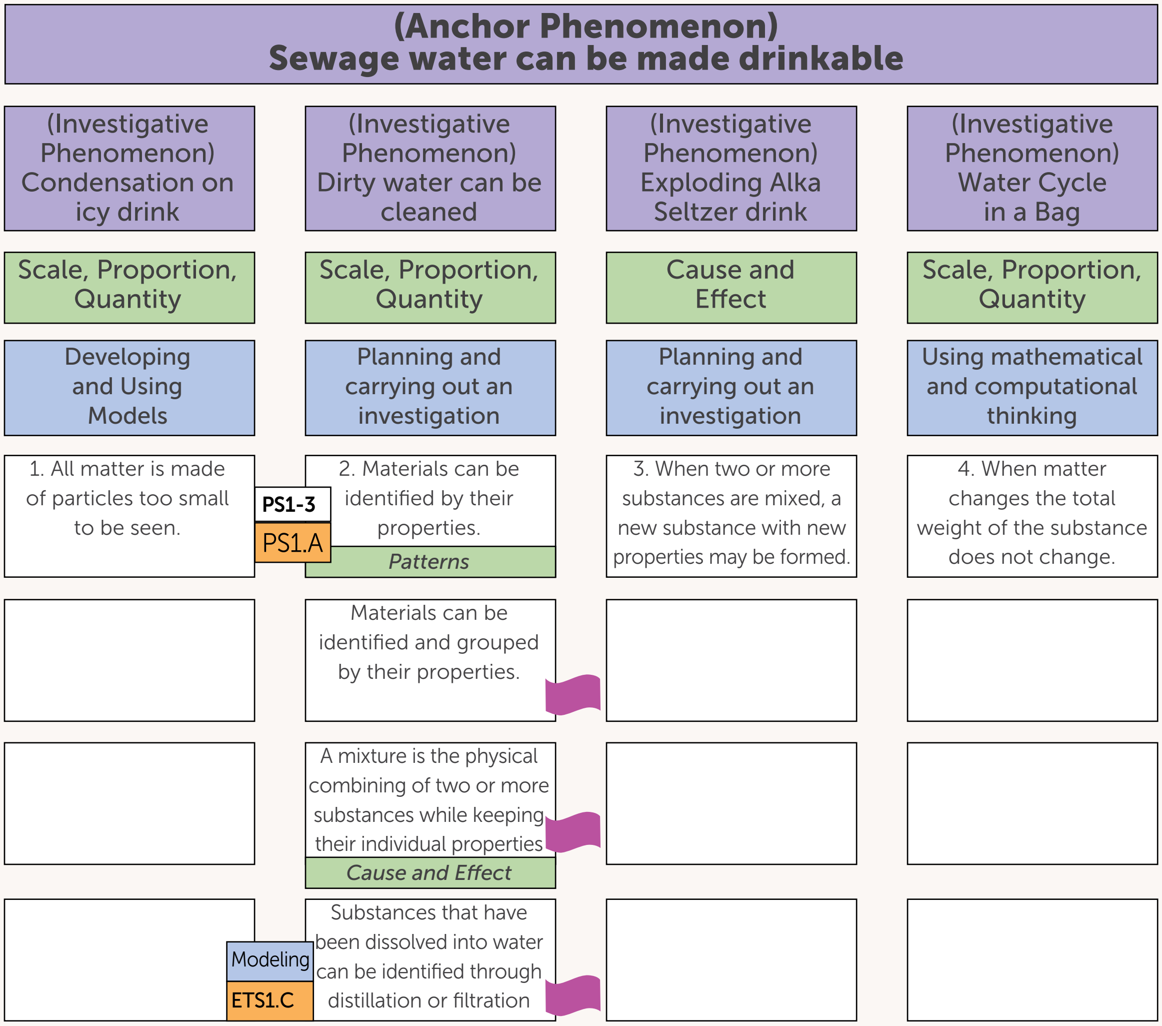
[6] A conceptual flow can be constructed for instruction lasting several weeks to a full academic year, depending on the complexity of the anchoring phenomenon and how many of the grade-level performance expectations are incorporated.

[7] See the *Glossary* for more information about each of the three dimensions.

Figure 2. Grade 5 conceptual flow for instructional unit on "What's in Our Water?"



(Anchor Phenomenon) Sewage water can be made drinkable			
(Investigative Phenomenon) Condensation on icy drink	(Investigative Phenomenon) Dirty water can be cleaned	(Investigative Phenomenon) Exploding Alka Seltzer drink	(Investigative Phenomenon) Water Cycle in a Bag
Scale, Proportion, Quantity	Scale, Proportion, Quantity	Cause and Effect	Scale, Proportion, Quantity
Developing and Using Models	Planning and carrying out an investigation	Planning and carrying out an investigation	Using mathematical and computational thinking
1. All matter is made of particles too small to be seen. **PS1-3** PS1.A	2. Materials can be identified by their properties. *Patterns*	3. When two or more substances are mixed, a new substance with new properties may be formed.	4. When matter changes the total weight of the substance does not change.
	Materials can be identified and grouped by their properties.		
	A mixture is the physical combining of two or more substances while keeping their individual properties *Cause and Effect*		
Modeling ETS1.C	Substances that have been dissolved into water can be identified through distillation or filtration		

Note: Purple = phenomena; green = CCCs; blue = SEPs; orange = DCIs; pink flags = possible assessment opportunities. Each column in this graphic represents a learning sequence.

The conceptual flow graphic differs from a concept map in that it addresses not only concepts in a unit of instruction, but also the hierarchy of ideas (indicating the relationships between and among the ideas) and the sequence for instruction. The collaborative work involved in developing a conceptual flow not only helps teachers deepen their understanding of how the three dimensions of the NGSS interconnect in instruction, but also strongly assists them in addressing some of the conceptual shifts associated with the NGSS (NGSS Lead States, 2013), including:

- Science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.
- Science concepts build coherently from kindergarten to grade 12.
- Students must be engaged in the nexus of three dimensions: Science and Engineering

Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

- The NGSS and the Common Core State Standards in English language arts (ELA) and math are aligned.

While developing a robust conceptual flow is time-intensive, the development process involves rich conversation that can serve as a powerful professional development experience, which, at a minimum, yields shared understandings. Conceptual flow graphics can be used by teachers not involved in the development process, but much of the value resides in the collaborative experience.

As a product, the conceptual flow provides the basis for development of a coherent, student-centered unit of instruction. Additional layers may be added to the conceptual flow to address connections to Common Core English language arts or mathematics as well as other content that relates to the conceptual storyline. Often, teachers will modify their conceptual flow over time with the mindset of continuous improvement.

Early Implementers' Reaction

Teachers and administrators have commented on the positive, powerful impact of using the conceptual flow to plan units of instruction:

> *My teachers use conceptual flows as a vehicle for planning interdisciplinary units and this has increased the rigor in those units. — Middle school site administrator*

> *Having done all the work needed to create a conceptual flow made me really think about the whole picture, understand the little parts, and have an organized "road map" to help me stay on track and keep focused on NGSS concepts. — Grade 3 teacher*

> *Conceptual flows were something I specifically learned from being a part of this [NGSS Early Implementers Initiative] grant. They have helped me unpack the standards, think deeply about misconceptions to avoid and connections I can make, and have helped me organize units. They have also decreased the amount of time I spend planning each week, because I have a guide map already. — Elementary school teacher*

> *Using conceptual flows (is valuable) because it forces planning to be very strategic and focused on learning rather than activities. — Grade 7 teacher*

"5E" Instructional Model for Developing Learning Sequences

As described above, the conceptual flow process yields an outline of a six- to eight-week instructional unit designed around a complex anchoring phenomenon. However, that conceptual flow outline does not include the details required to carry out instruction in the classroom. To enable educators to plan classroom instruction, the Early Implementers use the "5E" instructional model (the five "Es" are outlined below) to develop learning sequences that typically encompass multiple lessons.[8] Each learning sequence is based on one of the investigative phenomena in the conceptual flow graphic. As students explore investigative phenomena and the corresponding science concepts, they build understanding of the anchoring phenomenon.

The 5E instructional model is based on the constructivist approach to learning, which says that learners build new ideas on top of prior knowledge and understanding. It prompts lesson planning that is driven by student questioning, experience, and discussion to build new understanding. Originally developed by Biological Sciences Curriculum Study (BSCS; Bybee et al., 2006), the 5E instructional model, as used by Early Implementers, has five stages:[9]

1. **Engage**, in which students' interest is captured by experiencing or witnessing a scientific *phenomenon* or a problem to be solved. Students' prior knowledge is elicited about the science underlying the phenomenon or problem.
2. **Explore**, in which students are allowed to construct knowledge about the science related to the phenomenon through facilitated discourse, questioning, investigation, and/or observation. This should include peer-to-peer dialogue about their developing understandings.
3. **Explain**, in which students have time to refine and revise their thinking and explain what they have discovered. The instructor often facilitates a discussion of the science through *questioning strategies* to advance the students' understanding. In this stage, the emphasis is on the students doing the explaining, not the teacher.
4. **Elaborate**, in which students are asked to apply what they have learned in different but similar situations, and the instructor guides the students toward the next discussion topic.
5. **Evaluate**, in which teachers evaluate student learning and students have an opportunity to reflect on their learning. Evaluation should take place throughout the cycle, not just within its own set phase at the end.

From the beginning of the Initiative, Early Implementer teachers received hands-on training in how to use the 5E instructional model to plan lessons for the Teaching Learning Collaborative. The 5E model prompts teachers to plan student-centered, inquiry-based lessons or learning sequences in which students draw on their preconceptions, develop deep understanding of content (in contrast to relying on memory of facts), and engage in metacognition.[10]

At each stage of a 5E lesson, Early Implementer teachers follow a backwards design that prompts them to record the following information:

1. **What concepts to address:** Each stage has a three-dimensional concept, including specific DCI(s) as well as SEP(s) and CCC(s), although not all three may be foregrounded. The concept column is also the place to note relevant three-dimensional concepts from other content areas, such as English language arts, English language development, or mathematics. What the teacher and the student do is then developed to align with the three-dimensional concepts at each stage.
2. **What the teacher does:** Teacher questions/prompts (and follow-up questions/prompts) are chosen to advance student learning and elicit student responses and actions.

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[8] Because NGSS calls for 3D instruction, a learning sequence is seldom completed in a single class period.

[9] This description is derived from a Science and Children article, "5E for ELL" (Gomez-Zwiep, Straits, & Topps, 2015).

[10] The 5E model is consistent with research presented in the book, *How People Learn* (National Research Council, 2000).

3. **What the student does:** Expected student responses are identified based on the questions/prompts posed by the teacher.

For more details about the parts of the 5E instructional model, see the full handout provided to teachers by the K–12 Alliance, Explanation of the 5E Instructional Model in Appendix D.

NGSS Early Implementer Learning Sequences

The Early Implementers are involved in creating and field testing learning sequences based on grade-level conceptual flows, in which phenomena and big ideas in science are nested and linked to provide coherent conceptual understanding for students. The NGSS Early Implementer Learning Sequences[11, 12] are designed to provide examples of what phenomena-based, 3D learning looks like at a given grade level (see a sample learning sequence in Appendix E). Each NGSS Early Implementer Learning Sequence is a coherent arrangement of learning experiences in which student questions drive the discovery and understanding of the disciplinary core ideas and crosscutting concepts that help to explain the investigative phenomenon or solve a problem.

The titles of the NGSS Early Implementer Learning Sequences in grades K–8 are:

Kindergarten: Pushes and Pulls

1st Grade:	Sounds
2nd Grade:	Matter
3rd Grade:	Playground Forces
4th Grade:	Chain Reaction: Energy in Motion
5th Grade:	What's in Your Water?
6th Grade:	The Badwater 135
7th Grade:	Tree Mass: A Seedling Changes into a Large Tree
8th Grade:	Understanding White Sharks

Early Implementers' Reaction: 5E Instructional Model

Throughout the Early Implementers Initiative, the 5E instructional model has consistently been viewed by teachers as one of the most valuable processes that they utilize in planning NGSS instruction. The use of the 5E has significantly increased among participating teachers since the beginning of the Initiative. During the 2016–17 school year, 42 percent of all surveyed teachers reported using the 5E instructional model to plan lessons at least weekly (up from 13 percent during the 2014–15 school year), while 7.4 percent reported never using the 5E model (down from 55 percent in 2014–15). Teachers have related comments such as the following to evaluators:

> *Because the concept column is 3D, the 5E instructional model tool ensures lessons are 3D. When we facilitate lesson planning, teachers are often unsuccessful at making lessons 3D without this column as a reminder of the three dimensions.*
> *— Regional Director*

> *The 5E helped me structure my lessons and keep them moving in a productive way . . . the "Engage" portion of the lesson gets students excited and talking. The lesson sequence turned out to be a useful way*

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[11] The draft sequences were presented at the California Science Teachers Association (CSTA) California Science Education Conference in 2017 to positive reviews and were field tested by Teacher Leaders during the 2017–18 school year.

[12] The sequences will be available in late summer on the K–12 Alliance website (http://www.k12alliance.org) and will be presented as an encore at the 2018 CSTA California Science Education Conference.

> *for me to channel that excitement into the work of doing science. — Grade 5 teacher*
>
> *Using the 5E's, I learned to create a more student-driven learning environment. I gave less direct instruction and became more of a facilitator of learning. — Grade 6 teacher*

Early Implementers' Reaction: NGSS Early Implementer Learning Sequences

The NGSS Early Implementer Learning Sequences have been used in the Initiative for district in-service professional learning days. For example, one district convened all 7th grade teachers to spend a day working through how to teach an entire learning sequence. In another district, a more intensive training on the learning sequences was provided over a 10-day period. On a Saturday, facilitators led groups of grade-level teachers through part of the learning sequence as if they were students, and then the group discussed and debriefed implications for instruction. During the school week, the teachers tried teaching that part of the learning sequence in their own classrooms, and then reconvened the next Saturday to debrief.

One of the writers of the NGSS Early Implementer Learning Sequences reported that the experience "transformed how I thought about teaching through three dimensions and the value of arranging learning from a student-centered approach." A field-test teacher said, "[I] enjoyed the organization of the learning, the helpful teacher notes, and the suggestions for questions to help students push their thinking. I also like the links to other resources."

In observing district in-services, evaluators witnessed teacher engagement and heard how the learning sequences helped teachers in various ways, including showing them what NGSS-aligned instruction really looks like; eliciting and prompting better student engagement and learning; and giving them something to begin trying NGSS-aligned instruction. During a random observation of a kindergarten teacher who was trying a lesson from the sequence she experienced at the in-service, the teacher remarked, "I'm excited that my students came at the task in some different ways than what I predicted at the in-service. I'm not used to getting them to think this way in science and express their thinking — and this lesson got them to do it!"

Other teachers reported the following about their experience with learning sequences:

> *The 8th grade learning sequence, "Jawsome," was a great way to start the year and get my students thinking like scientists. They were faced with a very relevant and real-world phenomenon that was engaging and challenging for them to tackle. In the context provided by the learning sequence, students needed to read, write, collaborate, and create in order to accomplish the challenge set out for them. We had many discussions about what a claim is and how any claim should be backed up with evidence in science. Everyone grew tremendously, not only in their understanding of science, but also in their interest. — Grade 8 Core Teacher Leader*
>
> *It is rewarding teaching the NGSS learning sequences because the students question, explore, and discover on their own. — Grade 1 teacher*

Teaching Learning Collaborative

The Teaching Learning Collaborative (TLC) brings together groups of three or four teachers over two full school days, separated by one to three weeks. The first day is devoted to (1) either planning or choosing an existing conceptual flow created around an anchoring phenomenon, then (2) choosing a learning sequence with its related investigative phenomenon from the conceptual flow, and finally (3) developing a lesson according to the 5E instructional model. The second day involves teaching that lesson, then debriefing and revising it with an Initiative-trained facilitator (see Figure 3 for an overview of the two days). Originally developed by the K–12 Alliance in 1995, TLCs are a lesson-study approach based on the knowledge that the most effective professional development for teachers is that which occurs closest to the classroom (Cohen & Hill, 1998; Grossman et al., 2009; Putnam & Borko, 2000). All NGSS Early Implementer Teacher Leaders participate in two TLCs per school year, one in the fall and one in the spring, requiring a total of four release days out of the classroom.

Figure 3. Teaching Learning Collaborative flow

Planning Day		**Teaching Day**	
Setting the Stage	**Planning the Learning Sequence**	**Round One**	**Round Two**
• Introductions/ opener • Math/science update • Goals/purpose of TLC • Foundations of TLC • Setting norms • Logistics for teaching day	• Identify a learning sequence concept • Complete concept column in 5E instructional model template • Design for student thinking by completing the teacher and student columns • Develop questions and expected student responses (ESRs) • Review learning sequence design • Review logistics	1. Review teaching time; confirm that materials are ready 2. Review/rehearse teaching script and roles 3. Teach lesson 4. Debrief: effective, not effective 5. Use student work (got it/didn't get it) and facilitator notes for evidence of effectiveness 6. Determine priority of what to change for second lesson based on evidence 7. Redesign lesson including expected student responses	8. Re-teach 9. Debrief of second lesson: focus on effectiveness of the changes 10. Review ESRs (H, M, L) and develop rubric; Score student work 11. Discuss changes based on student work for next instruction 12. Debrief the process of conducting a TLC (learning, aha's, implications for all teaching and learning)

The Planning Day

During the planning day, the group of grade-level or grade-span teachers, typically from different schools within the district, begins by reviewing norms for collaborative work (see Appendix F). It is very important that the team members keep in mind that the TLC is not about evaluating one another's teaching ability. Rather, the purpose is to experience co-developing and co-teaching a lesson aligned to the NGSS, and then to collaboratively evaluate the lesson design. Through this process, teachers learn what phenomena-based, three-dimensional instruction is, how to use questioning strategies to encourage student discourse, and how to analyze student work to assess the effectiveness of the lesson.

When planning, the team focuses on specific content in science identified through the development of a phenomena-based 3D conceptual flow. They choose a relevant investigative phenomenon and a learning sequence from the conceptual flow to focus the learning. The 5E instructional model is then used to plan each stage of the lesson, beginning with introducing the selected phenomenon to the students, continuing on to using questions and prompts to advance student understanding,[13] and culminating in having students produce work that will be examined by the group during the debrief. Materials such as hands-on equipment, videos, readings, and sheets to record student work (if necessary) are chosen or prepared. Homework tasks are assigned to team members if all materials are not ready by the end of the day. The team also chooses the school and classroom(s) for teaching the lessons (i.e., the first lesson and the second, revised lesson).

The Teaching Day

At the start of the teaching day, the group reviews the lesson together, including the questions and prompts intended to elicit student understanding of the phenomenon. The team also assigns the parts of the lesson that each teacher will teach. They then visit the first classroom and teach the lesson. The facilitator takes detailed notes throughout. At the end of the lesson, the student work is collected, and the team departs the classroom to debrief with one another.

During the debrief, the teachers use evidence from the lesson — including facilitator notes, teacher observations, and student work — to discuss what worked and what was less effective, and which student responses were unexpected and why. The discussion focuses on the relationship between what the team included in the lesson planning and whether, in fact, students came away from the lesson with the desired understanding. They discuss the facilitator notes, share what they each noticed during the lesson, and discuss the evidence that indicates what students learned. They sort student work — sometimes into "got it" and "didn't get it" stacks, and sometimes into high/medium/low stacks based on a preliminary rubric. Student work samples are passed around or read aloud to facilitate calibration. Finally, the lesson is revised, based on evidence from the classroom and the student work, and the lesson is taught a second time to another group of students. After the second class, the team convenes again and reviews how the changes to the lesson impacted student understanding. The debrief concludes with teachers sharing the impact that the TLC process has had on their understanding of lesson planning and their efficacy to implement the NGSS.

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[13] See "Questioning Strategies That Promote Student Discourse" in the *Empowering NGSS Instruction* section of this report.

The Initiative has found the following conditions to be important for productive TLC experiences for all involved:

- The group should observe norms for collaborative work.
- The ideal team size is three to four teachers and may consist of same grade-level or grade-span teachers (e.g., a middle school team), cross-grade span teachers (elementary, middle, and high school teachers), or some combination thereof.
- Block schedules that allow teach times of 60–90 minutes work best, particularly for upper elementary and middle school (45–60 minutes for primary). A normal secondary schedule of 45- to 55-minute periods is difficult, but doable.
- Each debriefing session should be at least 60 minutes.
- The team should be led by a facilitator with knowledge of the NGSS and with expertise in facilitating and coaching adults.

Opportunity to Implement Key Science and Engineering Practices

With the advent of the NGSS, teachers are often new to incorporating the science and engineering practices and crosscutting concepts as a way for students to make sense of phenomena. The TLC provides an opportunity for teachers to design for this type of learning. Specifically, teachers often request help with two key practices that are central to student sense-making in science: (1) developing and using models and (2) constructing explanations. From the beginning, the Initiative emphasized the use of these two NGSS practices.

Models can be used as a way for teachers and students to begin to implement student-centered NGSS instruction. When using this practice, individual students are asked to create a model of their current thinking (often to show their prior knowledge) and then to continue to revise their model as they negotiate meaning. Individuals share their models with peers to make consensus models; groups publicly share their ideas for feedback from others; and eventually individuals return to their models for their final revisions.

Constructing explanations comes after extensive work with other practices such as gathering data that may serve as evidence; analyzing and interpreting data; and using models to explain phenomena. This practice fosters scientific reasoning by requiring students to answer a question by creating a claim grounded in scientific reasoning and supported by appropriate and sufficient evidence.

To help students construct an explanation, a simple graphic organizer is often used. For instance, students might write their claim in a box at the top of the page, their evidence in a middle box, and their reasoning in a box below. Teachers also provide sentence frames to scaffold the writing, such as the following:

> My claim is ____________. The evidence from my experiment/investigation to support this claim is _____________. The evidence from the text to support this claim is ____________. The science concepts that link my evidence to my claim are ____________________.

Early Implementers' Reaction

Principals who have observed TLCs often comment that they are impressed at the level of rigor involved. They remark on how teachers are able to critically frame productive questions that promote high-quality discourse in which students actively analyze problems and engage with complex questions.

Interviewed teachers report that the TLC is one of the most impactful professional learning experiences of the Initiative. They find that the opportunities to collaboratively plan and teach a lesson, and particularly to review student work, produce breakthroughs in understanding the NGSS in ways that directly influence their teaching.

Surveyed teachers reported that TLCs during the 2016–17 school year deepened their understanding of several key features of NGSS implementation. Specifically, over 80 percent of teachers felt their TLC experiences deepened their understanding of the disciplinary core ideas (DCIs), how to use science and engineering practices (SEPs) to teach science and engineering, and how to use the crosscutting concepts (CCCs) to teach science and engineering (84 percent, 80 percent, and 81 percent, respectively). Further, 78 percent of survey respondents felt their TLCs deepened their understanding of how to use a 3D approach to help students build understanding of a phenomenon.

The TLC experience has impacted Early Implementer teachers not only in their teaching of the NGSS, but in their teaching overall. They learn new habits of mind focused on student learning, as evidenced in their responses to post-TLC surveys, such as the following:

> *I have seen the importance of starting with a brainstorm of what a student should know to understand a phenomenon and then developing a storyline/conceptual flow regarding the particular science to study. I use [this process] for planning every subject. Also, allowing the students to generate "wonder" statements about a phenomenon is so important in making the learning personal and interesting.*
> *— Grade 4 teacher*

> *I learned how to make a lesson flow smoothly so that the concepts build upon one another. I also learned the importance of validating students' ideas and making them what drives the lesson forward.*
> *— Kindergarten teacher*

> *Make the crosscutting concept(s) you are teaching explicit. For example, if you want students to understand the cause and effect relationship of a phenomenon, write it on the board, refer back to it often, show exemplars, etc. A challenge of NGSS is a single phenomenon can be extremely rich in the learning, and you must help students focus the learning by being explicit about the CCCs.*
> *— Grade 6 teacher*

> *My big take away was how to really get students to create models. It needs to include the "why" not just labels.*
> *— Middle school teacher*

Empowering NGSS Instruction

This section describes the following Initiative items used in teachers' NGSS instruction:

- Looking at Student Work
- Questioning Strategies to Promote Student Discourse
- Sense-Making Through Student Notebooks

One goal of the Initiative is to have teachers using the above tools during NGSS instruction. To help teachers with this transition, these tools are often the topic of discussion on a Teaching Learning Collaborative (TLC) planning day, focusing on how the tools can be used to best access and develop student thinking. The earlier section on TLCs (in the *Empowering NGSS Lesson Planning* section) describes how teams of teachers first meet to plan instruction and subsequently meet again to teach the planned lesson. Therefore, readers may want to revisit the TLC section while reading through the NGSS instructional tools and strategies described in this section.

Looking at Student Work

Purpose

Promoting deeper student thinking — the ability to observe, ponder, ask questions, and then figure out real-world phenomena or solve real problems — is central to the vision of the Next Generation Science Standards. This vision suggests that teachers know how to look at, analyze, and interpret student work so that:

- Teachers can monitor and adjust instruction
- Students can monitor their learning
- Parents can be informed of student progress
- Program improvement can be monitored and adjusted

The Early Implementers utilize two specific looking-at-student-work protocols that enable staff and students to measure and reflect on student progress toward using science and engineering practices and crosscutting concepts to explain phenomena and solve problems while deepening understanding of core disciplinary ideas. Determining student progress lets teachers consider the effectiveness of the lesson. One looking-at-student-work protocol is designed to be used as part of the Teaching Learning Collaborative (TLC), the other as part of any regular professional learning community (PLC) in schools.

Looking at Student Work in a Teaching Learning Collaborative

In the TLC process, as teachers design the lesson, they create "expected student responses" to teacher prompts. These expected student responses are used to create the descriptions of high-quality student work. After the first time teaching the lesson they collaboratively designed, the TLC teams use the expected student responses and preliminary rubrics that they created based on the expected student responses to sort student work into performance levels. Groups sort student work by high, medium, and low performance. The teams then identify the characteristics of the lower-performance work to see where student learning might be improved. For example, if the characteristic indicates a common misunderstanding of a science SEP or limited use of a literacy skill, the team can discuss and agree upon ways to change the instruction to address the misconception.

In the debrief after the second time teaching the lesson they designed, teams again sort the student work into high, medium, and low performance. They determine the general characteristics of the student work at each level and record these characteristics on a group chart. Teams are encouraged to use qualitative descriptors rather than just quantitative measures. Next, they discuss the characteristics and determine if the original three piles should even be sorted into more levels — for example: high, medium high, medium, medium low, and low.

The characteristics of students' work are used to revise the preliminary scoring rubric. Based on the scores, and the descriptors for the levels, the team either re-designs the lesson one more time or engages in a discussion around what type of instructional strategy is needed to move students up from lower-level responses in the scoring rubric. (See Appendix G for a sample rubric.)

Looking at Student Work in a Professional Learning Community or Grade-Level Meeting

The second looking-at-student-work protocol can be used whether teachers have taught the same lesson and bring comparable, or "common," student work or bring "un-common" student work from different lessons (see Appendix H for the NGSS Common Student Work Protocol and Appendix I for the NGSS Un-Common Student Work Protocol). Teachers most often engage in this protocol during site-based PLCs or grade-level meetings. The protocol is designed to be used in a limited time period, which is generally about 50 minutes.

If the student work is common, the protocol allows the group to review the learning context and goals along with the expected student responses to the teacher prompt. The group determines the high, medium, and low responses in a method similar to the process used in the Teaching Learning Collaborative and then discusses strategies and interventions to move students up from one level to another.

As outlined in the sequence below, if the student work is un-common, the presenting teacher situates the lesson (steps 1–3 below) and then describes the student tasks (step 4) and the kinds of student responses expected (step 5):

1. Explain the essential question that is being investigated and the corresponding student learning goals
2. Explain where the work is situated in an instructional flow and describe the targeted NGSS three-dimensional goal(s)
3. If appropriate, provide any special instructional circumstances that could affect the possibilities of what students could have done
4. Briefly describe the task/prompt
5. Explain the expected student responses and the full range of actual student responses (i.e., high level of performance, medium level of performance, and low level of performance)

The group analyzes and interprets the student work and discusses implications for instruction while the presenter listens. At the end of the group discussion, the presenter has time to reflect on what she/he heard and what next steps to take.

Early Implementers' Reaction

Teacher Leaders report increasingly engaging in collaborative review of student work. While in 2014–15, only 15 percent of surveyed teachers said they deeply and systematically looked at student work with colleagues at least monthly, this percentage more than doubled to 34 percent in 2016–17.

By analyzing and interpreting student work, teachers can recognize the impact of their practices and the need to sometimes change them. In those cases, they are driven to find strategies to more consistently elicit student prior knowledge, help students build their conceptual frameworks, and use metacognitive strategies to consider how students came to understand. Teachers using the common and un-common student work protocols point to the benefits of working collaboratively to analyze the student work and identify areas to monitor and adjust instruction:

> *I have always had a hard time going back and looking at student work; I tend to determine the issues with a lesson on the fly. I realized that my visual review was good, but not as good as looking at students' work. I could really pin point where my students were having problems by looking at their work with colleagues; colleagues would see things that I didn't see. — Grade 2 teacher*

> *I used to think that I taught it; they just didn't learn it. Now I know that I have a responsibility to orchestrate student understanding. — Grade 7 teacher*

> *When I wanted to know if my students got it, I would look for responses from a couple of my students. Now I ask myself, "What do I need to do to engage the rest of the class?" — Grade 4 teacher*

Questioning Strategies to Promote Student Discourse

The Next Generation Science Standards focus on knowledge in use — the idea that students can make sense of the natural and built world and use that sense-making to solve novel questions and problems. In the classroom, the goal of NGSS-aligned instruction is to intentionally design opportunities for students to make sense of science through student discourse. Productive discourse makes student thinking public and provides authentic opportunities to build academic language. Discourse provides pathways for students to express their prior knowledge, negotiate new ideas, and refine their thinking.

Early Implementer trainings have consistently coached teachers on the strategic use of questions and prompts in their instruction that push their students to engage in sense-making and productive discourse. Through this sort of questioning, students take on the "heavy lifting" of learning, instead of teachers just giving students information to remember or telling students the answers. Teachers report that this shift toward promoting active learning and student discourse requires diligence and a shift in thinking, because for years many of them have seen delivering information to students as their primary responsibility. However, seeing the benefit of allowing students to take the time they needed to construct meaning and to independently solve problems has inspired many teachers in the Initiative to increase the use of facilitating questions to promote teacher-student and student-student discourse. The 5E instructional model, used in the TLC, helps identify critical places in a lesson where student dialogue would be particularly beneficial for sense-making.

There are several strategies that teachers use to design rich student-to-student discourse. In the Early Implementers Initiative, one strategy is to use a *Depth of Knowledge* schema to consider the level (or complexity) of questions that teachers ask students and that model for students how to ask such questions of each other. Depth of Knowledge is a widely used schema that helps teachers recognize how different questions require students to think at different levels of complexity. For example, a "recall" question requires students only to retrieve information, while a higher-level question might, for instance, require students to compare and contrast information to answer the question.

A second strategy for promoting rich student discourse is to use *accountable talk stems* that help students frame their discussions. These stems are often sentence starters or frames to help scaffold how students talk with each other. During "science talks," students use these stems to compare their findings with those of other individuals or groups. The stems can be used to:

- Ask questions (e.g., Why do you think ____? I was wondering about. . . .)
- Clarify what others are sharing (e.g., Say more about that idea. Tell me how you got that information. Explain your evidence.)
- Agree with what is being shared (e.g., My data also support _____because____.)
- Disagree with what is being shared (e.g., That's interesting, but my data show______. I hear you saying_____, but I think _______, because______.)

Both of these strategies (Depth of Knowledge and accountable talk stems) have been used extensively by the Initiative from its inception.

Crosscutting Concepts Can Frame Student Discourse

More recently, as the Initiative gained sophistication in teaching how to use the three dimensions, the NGSS crosscutting concepts (CCCs) were found to be a particularly fertile platform for increasing student-to-student discourse. Teachers were encouraged to use the CCCs as a means to develop questions that drive student thinking. For example, if students were using the CCC of "patterns" as a lens for observing leaves, they would notice different ideas than if they were looking through the lens of a different CCC, such as "scale and proportion."

To use the CCCs to create questions, teachers focused on the appropriate grade-band description for the target CCCs found in the NGSS.[14] For example, the description of CCC "patterns" at the K–2 level is, "Patterns in the natural and human designed world can be observed, used to describe phenomena and used as evidence." Teacher questions based on this element might include: What patterns did you observe in the various leaves? What trends did you notice in the data that could serve as evidence?

There was a strong feeling by Initiative directors and teachers that, once middle school students understood the use of CCCs and were building understanding of CCCs, they could independently use a tool that presented questions at progressive

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[14] Appendix G of the NGSS provides brief summaries illustrating how each crosscutting concept increases in complexity and sophistication across the grades as envisioned in the Framework. See https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Figure 4. Example of CCC-based student-to-student discourse tool for "cause and effect"

Identifying the cause of an event (whether there is one cause or many) helps us decide if there is relationship that can be explained, and, in some cases, it might inform a solution to a problem.

Entry Level	Increasing Sophistication	On-Target
I can use evidence to identify and analyze causes of events and design tests that gather more evidence. • What is the cause of this event? How do you know? • How does this cause help you identify a pattern? • How can you design a test to gather evidence (or refute ideas) about a possible cause?	I can identify cause and effect relationships to help explain change and the reason for the change. • What cause and effect relationship(s) can you identify? How did this change happen? Why did this change happen? • What conditions were needed for an event to happen? • What did you learn when you tested a cause and effect relationship? Do the results of this test help you explain change? If so, how? • If your observation/data show that two things happen together regularly — does it mean that one caused the other? How do you explain this? • What evidence do you have that one event caused (or didn't cause) another when the two things happen together regularly?	I can use evidence of cause(s) and effect(s) to decide the type of relationship between them and to predict future change. • Is this relationship you are seeing describing a cause that directly leads to an effect? Or, is the relationship describing two (or more) events that occur together where one may not cause the other? • What predictions can you make about phenomena, with confidence, based on this cause and effect relationship? What is your evidence for this? • How confident/sure are you? What else do you need to be more confident/sure? • What other cause might help you explain these phenomena? • How can a pattern in the effect, predicted by the cause, help describe phenomena? • How likely is it that this effect is going to happen? Why is this more or less likely?

Note: For complete resource, see http://k12alliance.org/docs/CCC-for-MS-Students.pdf

levels of sophistication to evaluate their own depth of understanding. With this in mind, and to make lessons at the middle school level even more student-driven, the idea of using the crosscutting concepts from a student's point of view was developed into a tool for student discourse. The CCC-Based Student-to-Student Discourse Tool turns the elements of each crosscutting concept into questions that can be used by students individually, in small groups, or in large group settings.

Figure 4 shows an example of the student tool for the CCC "cause and effect." To enable students to grow in their sophistication of using that crosscutting concept, the tool provides three levels of use: "entry," "increasing sophistication," and "on-target."

Students are introduced to the tool in ways that are similar to using accountable talk stems. Individuals or groups are provided with the chart and students are asked to select questions from it to help drive the conversation. As they gain confidence in using the tool, students independently select questions from the chart and are encouraged to formulate questions.

Early Implementers' Reaction

In surveys administered to all Teacher Leaders, the percentage of those who said they did not use questioning strategies to elicit student thinking dropped from over 20 percent during the 2014–15 school year to 2 percent in 2016–17. Similarly, the percentage of teachers who reported using questioning strategies to elicit student thinking at least once a week increased from 51 percent in 2014–15 to 72 percent in the 2016–17 school year.

Teachers at all grade levels have found questioning strategies to be beneficial to students as well as themselves:

> *Questioning strategies allowed me to guide students to understanding. I never provided answers but instead provided a pathway, which helped my students come to sense-making on their own and showed me their thinking along the way. This helped me better design future instruction as well as understand current thinking and any misconceptions. — Grade 6–8 teacher*

> *I believe the questioning strategies stimulated student thinking and engaged students to delve further into the nature of the phenomena of study, causing wonder and the desire to know more. — Grade 6 teacher*

> *Using open-ended questions and an inquiry approach generated conversation and helped students build on each other's ideas to create a class understanding. — Kindergarten teacher*

In addition, the following quotes show early reactions to the CCC-Based Student-to-Student Discourse Tool that helps students to frame questions to further their inquiry.

> *The CCC resource is an extremely helpful guide for me and my students. Using this guide initially as a teacher resource, I can help my students understand the depth of the CCCs for middle school students. As the students grow in their understanding and use of the CCCs, they can refer to the guide on their own to push themselves to move beyond "entry-level" to "increasing sophistication" and "on-target" demonstrations of the CCCs during learning experiences. — Grade 8 teacher*

> *I liked using the CCC chart with my group. At first, we weren't sure of what our observations meant. But the chart helped us first look for the effect (things we saw) and then helped us think about what was actually causing that to happen. — Grade 8 student*

Sense-Making Through Science Notebooks

In NGSS Early Implementer classrooms, science notebooks are used in the same way that scientists use them: to make sense of scientific concepts and phenomena. Rather than copying information dictated by the teacher, students use their notebooks to record their ideas and experiences. Like scientists, students record such things as observations, data, reasoning, patterns and connections they notice, information gleaned from readings or videos, predictions, questions, and plans for solving problems or getting answers to questions.[15]

The primary purpose of notebooks is for students to record their understanding as it builds over time. For example, at the start of a learning sequence or unit, students write about what they think they already know about a scientific concept or phenomenon. As they gather new information over the course of the unit, students update what they have written in their notebooks to make sense of new ideas, often using models to illustrate the progression of their ideas. Metacognitive prompts also help students record changes in their thinking, such as "I used to think . . . and now I think . . . " Furthermore, notebooks combined with discourse in the classroom promote English language skills in highly engaging ways for all students, including English learners.

A secondary purpose for the use of sense-making notebooks is for teachers to see where students are in their understanding, what misconceptions they may still have, and to use that information to plan classroom activities that will advance student learning. Teachers do look at notebooks, but, because the notebooks are used by students as scientists would use them, it is not appropriate for teachers to assign grades to notebooks. The notebook belongs to the student, just as a scientist's notebook belongs to the scientist. While the notebooks are not graded, written products that use evidence from the notebooks could be. Such products might include an informational paper or a claim with multiple lines of evidence from hands-on investigations documented in the student's notebook. These formal written products provide opportunities to address English language arts goals, such as writing for different audiences and for different purposes.

The K–12 Alliance has identified four "essences" of student thinking found in science notebooks that align with tenets of *How People Learn* (NRC, 2000):

1. *Prior knowledge*
2. *Gathering data*
3. *Making sense of data*
4. *Metacognition*

The essences are NOT explicit components of the notebooks, but should be present in the writings found in a student's sense-making notebook.

The following are detailed descriptions of the four essences:[16]

Essence of Prior Knowledge. All learners bring prior knowledge about a concept or phenomenon. Prior-knowledge notebook entries provide a starting point to build conceptual understanding of the phenomenon or the problem to be solved.

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[15] For more about science notebooks, including annotated pages from different grade levels, see the *California Classroom Science* article, "Sensemaking notebooks: Making thinking visible for both students and teachers!" (August 19, 2016) by K–12 Alliance Regional Director Karen Cerwin: http://www.classroomscience.org/sensemaking-notebooks-making-thinking-visible-for-both-students-and-teachers

[16] Adapted from "Sensemaking notebooks: Making thinking visible for both students and teachers!" (Cerwin, 2016).

Essence of Collecting Data. Asking questions about a phenomenon and defining problems is a basic science and engineering practice that often lays the foundation for gathering information or data. Collecting data enables the learner to begin to answer questions about the phenomenon or better define the solution to a problem. The data are further used in supporting students' arguments and explanations about the phenomenon. As upper elementary and middle school students grow in their use of data, they become better able to determine: (1) which data qualify as appropriate evidence for answering a question, supporting a claim, or solving a problem and (2) how to effectively display their data.

Essence of Making Sense of Data. As students conduct investigations, they make sense of the data they collect by recoding in their notebooks trends, causal or correlation relationships, validity, and reliability. Making sense of data enables students to determine what constitutes evidence for an explanation or a solution to a problem being solved. The early grades offer opportunities for students to see patterns, which often lead to cause and effect relationships in the data. Older students can observe patterns or trends that may or may not be related to the problem being solved. All ages record their evolving understanding of phenomena or problems based on the data. This, in turn, enables them to use data as evidence to construct arguments about methodology, results, and conclusions to support or rebut claims and explanations.

Essence of Metacognition. Expert learners know what they have learned and how new information fits into prior conceptual frameworks. Teachers working on developing students' metacognition carefully design prompts such as: What do you know for sure? What are you not sure of? I used to think ____; now I think___. What are three things I know about this phenomenon, two things I learned, and one thing I am wondering about?

Early Implementers' Reaction

Science notebooks have been a centerpiece of the NGSS Early Implementers Initiative since the first convening, and teachers have consistently rated them as one of the most useful tools for NGSS instruction. Evaluators have observed prominent discussion about use of student notebooks at every Summer Institute and training for Core Leadership Team members. Evaluators also have seen teachers building expertise in the use of notebooks for student sense-making during TLC teach days, and in observations in classrooms of case-study teachers.

In surveys administered to all Early Implementer teachers (i.e., Core Teacher Leaders and Teacher Leaders), the percentage of teachers who said they did not use science notebooks for student sense-making dropped from over 40 percent during the 2014–15 school year to 5 percent in 2016–17. Similarly, the percentage of teachers who reported using notebooks for student sense-making at least once a week increased from 28 percent in 2014–15 to 67 percent in the 2016–17 school year.

Teachers and administrators alike attest to the value of science notebooks for both learning science and developing English language skills:

> *You can see the whole earth science unit, the sun, moon, and stars, from the beginning to the end in their notebook. And they're so proud of it. I couldn't live without them now. I love them. The kids love them too. That's what's really neat, that*

that they take such ownership of them. — Grade 2 teacher

When I was first introduced to everything, I really was drawn to the use of the notebooks for the students. I liked letting the students express themselves in their own way. Especially working with the language-learning population, I think that it's important to acknowledge that that allows language learners to express themselves in their learning where they're not restricted to the confines of language conventions. — Grade 5 teacher

I think now they believe me that you really aren't going to be penalized for being wrong. We would like you to grow in your thinking, and we would really like you to look at that data thoughtfully, but what you think, and the conceptual frameworks you come up with, are what you come up with. They're much braver than they used to be because we're allowing them to be. — Grade 8 teacher

Empowering Administrator Support of NGSS Implementation

The three items listed below are used by the Initiative to empower administrators' support of NGSS implementation.[17]

- Principal Academy
- Walk-Through Protocol
- Evidence of Learning Protocol

The *Principal Academy* is the equivalent of five days per year of professional learning that the Initiative provides for administrators. The *Walk-Through Protocol* and *Evidence of Learning Protocol* are used during this professional learning (we have included separate entries for them in this section in order to provide a good understanding of each).

Principal Academy

As we have reported elsewhere, leaders of the Initiative discovered early on how crucial the role of the principal is to the success of teachers and their students. The Principal Academy was initiated in year 2, and expanded in years 3 and 4, to more directly involve and mentor site administrators who could then drive NGSS implementation in their schools.

The Principal Academy was created for all principals who had Core Teacher Leaders or Teacher Leaders at their site. The Academy is a five-day equivalent program that uses mixed platforms for the professional learning, including:

- A one-day meeting held with the Teacher Leader Summer Institutes
- One day participating in a Teaching Learning Collaborative in their district
- One half day in school walk-throughs
- A total of two and a half days in which participating principals are mentored on self-selected topics that will help them move the implementation of the NGSS forward at their school sites

Principal Academy Summer Institute Meetings are held during the Teacher Leader Summer Institutes. In these meetings, principals receive science education updates from state policymakers, network with each other and their Teacher Leaders, and learn with their peers about the pedagogical shifts of the NGSS and how to support NGSS implementation in their schools and districts. They select and attend sessions of interest related to their chosen areas of mentorship. Academy sessions such as the following have been offered:

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[17] How the Initiative is strongly involving administrators is more fully described in an earlier evaluation report (#3), *Administrators Matter in NGSS Implementation: How School and District Leaders Are Making Science Happen.* See https://www.wested.org/resources/administrators-matter-ngss-implementation/

- Ensuring equity and access to quality science instruction for all students
- Linking science assessment and instructional strategies
- Identifying characteristics of an NGSS classroom
- Implementing the NGSS at the middle school
- Supporting integration of NGSS and Common Core State Standards
- Building a culture of change and innovation
- Supporting science as a core subject

Teaching Learning Collaboratives (TLCs) are held for groups of teachers during the school year. Principals are invited to attend one TLC planning day, if they can, and are requested to attend one teaching/debrief day. The principals' district Project Director for the Initiative coordinates scheduling and joins principals at the TLC(s) to facilitate their participation and learning. During the debrief, principals use the Evidence of Learning Protocol[18] to deepen their understanding of what NGSS looks like in the classroom and how to plan for effective student-driven teaching and learning.

Science walk-throughs occur at individual school sites and can be spread over a period of time and in a variety of classrooms. Regional Directors, as well as either Project Directors, Core Administrators, and/or Core Teacher Leaders, accompany principals during the walk-throughs. The group discusses their observations in order to both help administrators understand NGSS instruction and profile the school's progress toward the instructional shifts required by the NGSS.

Individualized mentoring builds on learning about the self-selected topic from the Summer Meeting. Principals with a similar identified topic are assigned a mentor (Regional Director, Project Director, or Core Administrator) who will work with them as a group to address the topic as it plays out at their sites. Mentoring might focus on:

- Building a school culture that makes science a priority
- Using notebooks in all content areas
- Encouraging student-centered instruction

Strategies for mentoring principals have included the following:

- Presenting to groups of principals during meetings
- One-on-one discussion and question-and-answer
- Additional TLC or walk-through experiences in which one or more principals engage in conversation with Early Implementer leader(s) about what was seen

Early Implementers' Reaction

The extent of principal participation in Academy activities has varied across the districts. When principals attended the Summer Institutes, they were able to participate in the "kick-off" and select their chosen topics for mentoring during the school year. If principals did not attend the Summer Institute, it was a greater challenge for the Project Directors to recruit principals to other activities during the year. Nonetheless, all districts saw increasing levels of principal involvement in Academy activities over the course of the initiative.

For example, one principal who had already attended a TLC went on a walk-through with a Regional Director. They visited two classrooms,

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[18] The Evidence of Learning Protocol is described in its own section below.

one taught by an Early Implementer Teacher Leader, the other by a teacher without NGSS training. They focused on how teachers were supporting student learning during science instruction. The principal noticed that there was a big difference between the two classes in the use of notebooks to support student understanding. The Regional Director then arranged for the principal to meet with the district Project Director and the two Teacher Leaders at the principal's school. Together they created a staff presentation on the use of notebooks in science.

Another administrator reported the following:

> *I love the Summer Institute, as it gives me time to understand and make the connections. I also love seeing the Early Implementer teachers do lesson studies [TLCs] in real time with students. This truly shows what happens in a science lesson and shows that students can engage and are motivated to participate. This helps me provide better feedback to teachers. — Elementary school principal*

Enhancing both participation levels and the professional learning experiences for principals is a strong emphasis of the Initiative during its concluding years (years 5–6).

Walk-Through Protocol

In Early Implementer districts, science walk-throughs can be conducted by school leadership teams consisting of the principal, Teacher Leaders, and any coaches. In these walk-throughs, participants briefly observe a number of science classrooms in succession. The observations, which are five to ten minutes long, serve as opportunities to collect data on the quality of science instruction at the school level. The team uses an observation tool during the walk, and during discussion afterward a reflection tool is used to analyze data and identify next steps. Both tools were originally developed by one Early Implementer district, and then adapted for use by other districts in the Initiative as part of the Principal Academy.

The science walk-through serves three main purposes:

1. **Leadership tool for instructional improvement:**[19] Science walk-throughs provide valuable information relating to schoolwide patterns of science instruction. They engage the school leadership in evidence-based discussions about the current state of NGSS implementation at the school and on how to continue to strengthen schoolwide instruction in science, with particular focus on issues of equity. Data from the observations are used to plan next steps and design professional learning for teachers.
2. **A way to develop a shared understanding of quality science instruction for school and district leaders:** By focusing on the three-dimensionality of NGSS, science walk-throughs also provide a shared experience for administrators and other school leaders and help them develop a shared understanding of what strong NGSS-aligned instruction can look like.
3. **A measure of districtwide NGSS implementation:** As more school leaders conduct walk-throughs and share data regarding patterns of instruction with district leadership, the state of science instruction in the district comes into clearer focus. With districtwide implementation, this practice can provide a

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[19] It is important to note that science walk-throughs are used to gather data on pedagogical patterns of instruction at the school level, not as an evaluative tool at the teacher level.

measure of the pedagogical shifts taking place systemwide.

There are two sets of norms used by the leadership team, one for conducting classroom observations and one for the post-observation group work. The leadership team reviews and discusses these classroom observation norms[20] before conducting the walk-through:

- Uphold norms of confidentiality regarding the visits
- Do not evaluate; emphasis on learning
- Be a learner
- Refrain from making judgmental comments
- Disrupt instruction as little as possible
- Focus on observational evidence and be as explicit as possible
- Do not make inferences

As they conduct the walk-through, each group member completes a separate walk-through tool for each classroom visited (see Appendix J). The tool prompts them to focus their observation notes in four areas:

1. **The task:** What is the focus question? What are students trying to answer or what problem are they trying to solve?
2. **The content:** What is the content? Is it aligned to grade level three-dimensional learning? How does the content outline rigorous expectations?
3. **The teacher:** What is the teacher doing? How is the instruction allowing all students to do the thinking and three-dimensional learning?
4. **The students:** What are the students doing? How are the students interacting — with each other, the teacher, the task, and the three dimensions? How are students developing scientific understanding?

After visiting a series of classrooms, the team sits down to debrief, observing the following group work norms:

- Be open to new learning
- Actively cultivate a safe space for learning
- Push yourself to take risks and grow
- Persevere through the messiness (keep the big picture in mind for opportunities for growth and learning)

The walk-through debrief includes a silent period when all team participants write their notes one by one on Post-its, including quantitative data (e.g., in four of five classes students were discussing in pairs). They share their observations one at a time and then identify patterns across the classes. The discussion can be guided by the following prompts:

- What was the task? How engaged were students in the task?
- How were students able to articulate their understanding?
- Was the task aligned to the grade-level standards?
- Which dimensions were being taught/learned (DCI, SEP, CCC)?
- What strategies did the teacher use to facilitate the learning?
- What were the literacy opportunities?
- What were the language opportunities and demands of the lesson and how were they addressed?

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[20] Adapted from *"What to Look For" Observation Guides*, Massachusetts Department of Education's Center for Instructional Support (August 2017).

The collected data is used to complete the walk-through reflection tool (see Appendix K), which prompts the school leadership team to analyze successes and challenges in the school relative to NGSS implementation, reflect on root causes of these successes and challenges, and determine professional development needs. This tool encourages thoughtful reflection about how the school got where it is, both in terms of successes and challenges, and how to move forward.

As science walk-throughs become embedded in the culture of the schools, they provide ongoing formative assessment of progress of NGSS implementation schoolwide and can also serve to provide feedback to all teachers on instructional practices.

Early Implementers' Reaction

The following comments illustrate views that administrators have been expressing about the usefulness of science walk-throughs.

> *The walk-through tool was valuable. I was having a hard time understanding what I should be looking for in a classroom and the tool clarified this for me. It also helped me to identify the areas where I am weak in understanding the three-dimensionality of NGSS. — Principal at K–5 site*

> *I appreciated the simplicity of the walk-through tool. It allowed me to jot down observations and I was able to use this to start a conversation with my teachers. — Principal at 6–8 site*

Evidence of Learning Protocol

The Evidence of Learning Protocol is a three-part tool designed by the Early Implementers Initiative to foster and focus principal and/or teacher learning about NGSS instruction when observing science lessons. The ultimate goal of the Evidence of Learning Protocol is to share the vision of NGSS instruction such that principals and administrators are better able to support teachers as they implement the new standards.

The protocol has been used in three contexts: to facilitate communication between a principal and a teacher about a lesson observation; to focus conversations about lessons observed by a teacher team at a school; and to help principals gain understanding of key features of NGSS lessons when observing a Teaching Learning Collaborative (TLC) lesson as part of the Principal Academy.

In all three cases, principals or teachers meet in advance of the lesson to be observed with the teacher who will be teaching the lesson. The following description primarily focuses on the third use of the protocol in the list above (i.e., helping principals gain understanding of key features of NGSS lessons) because the Initiative is proactively enlisting administrators to try this as part of the Principal Academy.

The three parts of the Evidence of Learning Protocol are:

- The Evidence of Learning Protocol Matrix
- The Pre-Conference Planning form
- The Notetaking form

The Evidence of Learning Protocol Matrix is the central part of the protocol. It lists four elements of NGSS instruction: phenomena-based

Figure 5. Evidence of Learning Protocol Matrix — Phenomena-based instruction element

Elements of meaningful three-dimensional learning in science	Planned (Observe via planning documents)	Enacted (Observe the actions of the students and teacher)	Assessed (Observe through student work)
Phenomena-based (as defined by SEPs, DCIs, CCCs)	• Teacher selects appropriate phenomena for lessons (i.e., phenomena meet the needs of and are relevant to learners *and* phenomena have explanatory power)	• Teacher provides content-rich experiences (e.g., hands-on activities, video depiction, simulation of the phenomena) • Teacher elicits prior knowledge on all three dimensions through questioning, content-rich experiences, initial models, etc. • Students engage in the phenomena through experiences that approximate the work of scientists and engineers • Teacher and students use the three dimensions to begin to make sense of the presented phenomena	Students: • Demonstrate an understanding of phenomena (e.g., science notebook entry, diagram, science talk, other evidence of student thinking) • Make connections between phenomena and everyday life

instruction, changes in student thinking, conceptual coherence, and connection to Common Core State Standards. The Matrix provides, from both a teacher and student point of view, what each element should look like in three phases of instruction: what is planned, what is enacted in the classroom, and what student work can be assessed. Administrators use these criteria as guidelines for what to look for while reviewing the lesson plan before instruction, observing the actions of the students and the teacher during the lesson, and reviewing student work after the lesson.

For example, see the Matrix description for the "phenomena-based instruction" element in Figure 5. (See Appendix L for the complete NGSS Evidence of Learning Protocol Matrix, including all four elements.)

When the Evidence of Learning Protocol is used as part of the Principal Academy, teacher teams select the element they think the lesson incorporates most strongly, or the element on which they want to push their understanding. They make their selection at the end of the planning day and complete a Pre-Conference Planning form. Prior to the teaching day, the principal meets with the district Project Director or Regional Director to review the lesson planning documents. They also review the Evidence of Learning Protocol Matrix, focusing on the element pre-selected by the TLC team of teachers as the focus of principals' observation.

During the TLC lesson, principals look for readily noticeable enactment of the element, and may record their impressions on the Notetaking form. During the TLC debrief sessions, principals offer comments after the teachers have voiced their evaluation of how the lesson went, scored student work, and begun to redesign the lesson based on what they agree was less effective. Principals are encouraged to add to the effective/less effective conversation, focusing on the element selected for them by the team.

Early Implementers' Reaction

The evaluation team has observed that administrators can use this tool and find it to be effective for focusing their attention and promoting their NGSS understanding when participating in a TLC. It was impressive to see that administrators had indeed taken the time to meet with participants ahead of time and were willing to "buy in" to using the forms to focus their classroom observation and their subsequent discussions with teachers during the debrief. One administrator remarked:

> *Being a part of the lesson planning, the observation and the debrief was extremely powerful, and the tool allowed us to focus in on the specific phenomena. The strong connection to the real-world problems and phenomenon is so engaging and grounds students' learning in personal experiences around that phenomenon. — Elementary school principal*

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Appendix A. Links to Other Related Resources

This appendix briefly describes resources from outside the NGSS Early Implementers Initiative that are also a source of tools and processes to support NGSS implementation. These reports have information that is complementary to this collection of tools and processes used by the NGSS Early Implementers.

Five Tools and Processes for NGSS

American Museum of Natural History (n.d.)

https://www.amnh.org/explore/curriculum-collections/five-tools-and-processes-for-ngss/

In collaboration with BSCS and the K–12 Alliance at WestEd, the Gottesman Center for Science Teaching and Learning at the American Museum of Natural History developed and field-tested five tools and processes for professional development leaders. These tools are a timely and appropriate response to the challenges of translating the NGSS into instruction and classroom assessment. These tools and processes establish a meaningful context for teachers of science to develop an understanding of the framework and the NGSS, as well as a means to begin implementing changes in their classrooms.

STEM Teaching Tools

University of Washington Institute for Science + Math Education (2018)

http://www.stemteachingtools.org/

The STEM Teaching Tools site has tools that can help you teach science, technology, engineering and math (STEM).

A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas

National Research Council (2012)

https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

This framework, "proposes a new approach to K–12 science education that will capture students' interest and provide them with the necessary foundational knowledge in the field." California's NGSS and framework used the National Research Council framework as a foundational guiding work.

NextGen TIME: Professional Learning for Next Generation Science

BSCS

https://nextgentime.bscs.org

NextGen TIME is a suite of tools and processes for curriculum-based professional learning that supports educators to evaluate, select, and implement instructional materials designed for next generation science. Available for *free*, NextGen TIME offers a system that challenges and enables educators to use the instructional materials selection process as something more than just choosing better materials. These resources can be used as a lever for supporting teacher implementation of next generation science and improving science instruction for all students.

Appendix B. Criteria for Selecting Useful Phenomena

Scientific phenomena are occurrences in the natural and human-made world that can be observed and cause one to wonder and ask questions.

Phenomena-based instruction is a primary feature of the NGSS classroom. A three-dimensional learning approach requires students to use the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas in concert to explore, investigate, and explain how and why phenomena occur. The complexity of a student explanation should be appropriate to the learning progression at the grade span.

Phenomena do not have to be phenomenal. Often simple events, when looking at them through a scientific eye, can elicit curiosity and questions in students and adults. Such wonderment is the beginning of engagement in which answers to questions are sought.

When choosing useful phenomenon for classroom use, the scale or size of phenomena is important. Determining the grain size of a phenomenon involves consideration of the length of instructional time required to teach it, the depth of student explanation possible, and the complexity of the phenomenon itself. Often an anchoring phenomenon can be broken down into smaller investigable phenomena in the same way a jigsaw puzzle can be broken down into individual pieces. By having students observe and explain smaller related investigative phenomena first, they can then be challenged to explain the larger and more complicated anchoring phenomenon.

Anchoring Phenomena

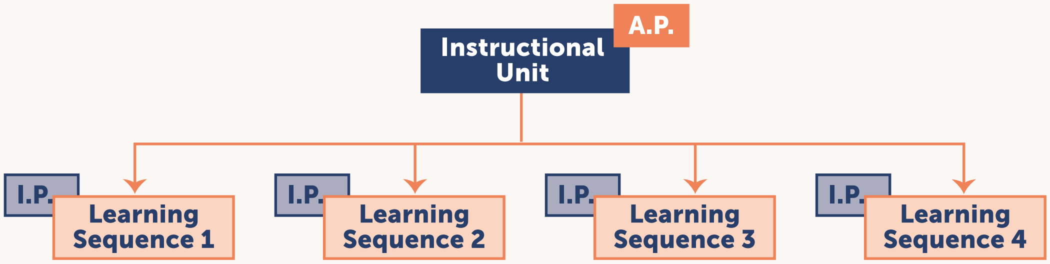
Anchoring phenomena are the focus of a larger instructional unit/instructional segment, and connect student learning across multiple weeks of instruction. They often require significant or in-depth understanding of several related science ideas as well as multiple lines of evidence and reasoning to adequately explain. Because of their size or scale, students may only be able to explain aspects of an anchoring phenomena.

Investigative Phenomena

Investigative phenomena are used in instructional sequences (across several lessons) to provide students personal experience with observable events where an evidence-based explanation can be constructed. Investigative phenomena may relate to larger anchoring phenomena. They often require understanding or use of a fewer number of connected science ideas to explain.

Use the following guiding questions and criteria to help determine if a phenomenon under consideration is useful or not:

Figure B1. Anchoring and investigative phenomena in a conceptual flow



- Can students **observe** and/or **investigate** the phenomenon either through firsthand experiences (e.g., directly in a classroom, lab, or outdoor environment) or through someone else's experiences (e.g., through video presentations, demonstrations, or analyzing patterns in data)?
- Do students need to understand and use **Core Ideas**, **Science and Engineering Practices,** and **Crosscutting Concepts** to explain how and why the phenomenon occurs?
- By making sense of the phenomenon, are students building understanding toward grade-level **performance expectations**?
- Would student explanations of the phenomenon be **grade-level appropriate**?
- Is the phenomenon **anchored** in real-world issues or the student's local environment?
- Will students find making sense of the phenomenon **interesting** and **important**?
- Does the potential student learning related to the phenomenon justify the **financial costs** and **classroom time** that will be used?

For phenomena resources, visit:
http://www.sciencephenomena.com/

SDCOE NGSS Resource Center:
https://ngss.sdcoe.net

This tool is an adaptation of the following resources:

Qualities of a Good Anchor Phenomenon for a Coherent Sequence of Science Lessons from William R. Penuel and Philip Bell, Research + Practice Collaboratory

Three-dimensional instruction: Using a new type of teaching in the science classroom from Joe Krajcik, NSTA Science Teacher

Criteria for Evaluating Phenomena from Ted Willard, NSTA

Contributors: Kirk Brown, Teryl Burditt, Sean Timmons, Karen Cerwin, Jim Clark, Chelsea Cochrane, Kathy DiRanna, Nikki DiRanna, Michael Goodbody, Jill Grace, Wendy Hagan, Crystal Howe, Jennifer McCluan, Dawn O'Connor, Cheryl Peach, Christie Pearce, Maria C. Simani, John Spiegel, Jo Topps

Appendix C. Possible Phenomena by Grade Level (K–8)

Possible Elementary Phenomena

Kindergarten

Phenomenon	Topic
• A player moves a soccer ball across a field to make a goal	Force and motion (K-PS2-1)
• Puddles at school dry out on a sunny day • My M&M's melted in the sun • It hurts to touch the blacktop on a sunny afternoon	Effect of sunlight on Earth's surface (K-PS3-1)
• Sometimes I wear a jacket at school and sometimes I don't	Weather patterns (K-ESS2-1)
• A weed is growing in a crack of concrete	Patterns of what plants and animals need to survive (K-LS1-1)

Grade 1

Phenomenon	Topic
• Hummingbirds built a nest outside our classroom	Parent behavior that helps offspring survive (1-LS1-2)
• A fire truck siren communicates information	Sound and vibration (1-PS1-4)
• I couldn't find the broom in the dark closet at school	Electromagnetic radiation (1-PS4-2)
• The sun in different positions at school during the day	Patterns of motion of sun, moon, stars (1-ESS1-1)

Grade 2

Phenomenon	Topic
• After the sprinklers come on, there is a gully on the playground	Wind and water can shape the land (2-ESS2-1)
• The squirrel at our school is burying seeds • Sometimes, when I walk across a field, my socks get burrs on them	Animals disperse seeds (2-LS2-2)
• The crayons I left in my car melted	Materials have different properties (2-PS1-1, 2-PS1-2)

Grade 3

Phenomenon	Topic
• Wind can move some objects farther than others	Forces and motion (3-PS2-1)
• The bugs in my compost pile keep changing	Life cycle patterns of birth, growth, reproduction, and death (3-LS1-1)
• One magnet can make another move without touching	Electrical and magnetic interactions (2-PS2-3)
• Objects move in different ways on the playground	Predicting motion (3-PS2-2)
• When I look at photos of the same landmark near the school in different types of weather, the landmark looks different	Weather conditions during a season (3-ESS2-1)

Grade 4

Phenomenon	Topic
• Objects move in a rube goldberg	Energy transfer (4-PS3-2)
• This marine snail looks really different from the snails in my backyard	Structures to support survival (4-LS1-1)
• Two skateboarders crash and one moves further than the other	Speed and collision (4-PS3-1)
• Our school has seashells in the dirt • The road cut by our school has visible layers	Evidence for changes over time (4-ESS1-1)

Grade 5

Phenomenon	Topic
• A giant sequoia is really tall; taller than a normal tree	Plants get what they need from air and water (5-LS1-1)
• The gate at school is rusty • The statue in our community has turned green • I made a cake from liquids and solids	Creation of new substances (5-PS1-4)
• I saw a video where they made reclaimed water safe to drink	Properties of matter (5-PS1-3)
• Material in my compost bin changed over time	Movement of matter (5-LS2-1)
• So far, we haven't seen life on the moon	Earth systems/spheres (5-ESS2-1)

Possible Middle School Phenomena

CA NGSS integrated topics and possible phenomena
Grade 6

Topics	Phenomenon
• Cells and organisms • Earth surface processes • Weather and climate • Temperature/thermal energy	The human body deals with extreme stress when competing in the Badwater 135 Ultramarathon
• Cells and organisms • Inheritance • Growth and development • Earth surface processes • Weather and climate • Global climate change • Human impacts	There is an unusually high number of sick adult California sea lions along the coast of California
• Weather and climate • Global climate change • Temperature/thermal energy • Conservation of energy • Human impacts • Engineering	Increased afternoon winds in our city
• Earth surface processes • Weather and climate • Temperature/thermal energy • Conservation of energy • Human impacts • Engineering	Great Pacific garbage patch was recently discovered
• Cells and organisms • Growth and development • Inheritance • Earth surface processes • Global climate change • Human impacts	Gray whale migration patterns have changed in recent years

CA NGSS integrated topics and possible phenomena
Grade 7

Topics	Phenomenon
• Matter and energy flow in organisms • Matter and energy flow in ecosystems • Chemical processes of life • Ecosystem dynamics • Biodiversity • Human impacts • Engineering	Local invasive species X are outcompeting species Y for space
• Matter and energy flow in organisms • Matter and energy flow in ecosystems • Chemical processes of life • Ecosystem dynamics • Matter structure/properties • Human impacts	Ocean acidification is having a negative impact on salmon biomass
• Ecosystem dynamics • Earth surface processes • Natural hazards • Human impacts • Engineering	Our community is prone to landslides
• Matter and energy flow in organisms • Matter and energy flow in ecosystems • Chemical processes of life • Ecosystem dynamics • Biodiversity • Plate tectonics and Earth structure • Earth surface processes • Human impacts	There has been a reduction in Julian Apple yield in recent years
• Earth materials and systems • Earth surface processes • Natural resources • Matter structure/properties • Chemical reactions • Human impacts • Engineering	There is an increase in the occurrence of sinkholes in our community

CA NGSS integrated topics and possible phenomena
Grade 8

Topic	Phenomenon
• Variation • Adaptation • Forces and motion • Kinetic/potential energy • Energy and forces • Conservation of energy	Flipping your skateboard
• Adaptation • Human impacts • Earth history • Forces and motion • Wave properties • EM radiation • Information technologies • Engineering	There is a reported increase in white shark encounters in the waters off Southern California and the public is worried
• Universe and stars • Earth and Solar System • Forces and motion • Energy and forces • Wave properties • EM radiation • Information technologies • Engineering	NASA is developing plans for human long-term space travel
• Ancestry and diversity • Natural selection • Universe and stars • Earth history • Force and motion • Energy and forces	Catastrophic bombardment was common in the Earth's ancient past, and there is evidence it's not over
• Inheritance • Variation • Adaptation • Universe and stars • Earth and Solar System • Human impacts • Force and motion • Engineering	The trend towards feeding your community locally: more people are eating food grown closer to the source

Appendix D. Explanation of the 5E Instructional Model

Stage	Teacher Does Learning Experience (strategies/activities)	Student Does	3D Concept
ENGAGE Initiates the learning task. The activity should make connections between past and present learning experience and anticipate activities and organize students' thinking toward the learning outcomes and current activities.	• Creates interest • Generates curiosity • Raises questions and problems • Elicits responses that uncover students' current knowledge about the concept/topic	• Asks questions such as: Why did this happen? What do I already know about this? What can I find out about this? How can this problem be solved? • Shows interest in the topic	Prior knowledge of concept to be learned
EXPLORE Provides students with a common base of experiences within which current concepts, processes, and skills are identified and developed.	• Encourages students to work together without direct instruction from the teacher • Observes and listens to students as they interact • Asks probing questions to redirect students' investigations when necessary • Provides time for students to puzzle through problems • Acts as a consultant for students	• Thinks creatively within the limits of the activity • Tests predictions and hypotheses • Forms new predictions and hypotheses • Tries alternatives to solve a problem and discusses them with others • Records observations and ideas • Suspends judgment • Tests ideas	Concepts to explore to build understanding of "explain" concept

Stage	Teacher Does Learning Experience (strategies/activities)	Student Does	3D Concept
EXPLAIN Focuses students' attention on a particular aspect of their engagement and exploration experiences; provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to introduce a concept, process, or skill after student sense-making, to help students align language for improved scientific accuracy.	• Encourages students to explain concepts and definitions in their own words • Asks for justification (evidence) and clarification from students • Formally provides definitions, explanations, and new vocabulary • Uses students' previous experiences as the basis for explaining concepts	• Explains possible solutions or answers to other students • Listens critically to other students' explanations • Questions other students' explanations • Listens to and tries to comprehend explanations offered by the teacher • Refers to previous activities	Concept student knows or understands
ELABORATE/EXTEND Challenges and extends students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills.	• Expects students to use vocabulary, definitions, and explanations provided previously in new context • Encourages students to apply the concepts and skills in new situations • Reminds students of alternative explanations • Refers students to alternative explanations	• Applies new labels, definitions, explanations, and skills in new, but similar, situation • Uses previous information to ask questions, propose solutions, make decisions, and design experiments • Draws reasonable conclusions from evidence • Records observations and explanations	Concept application

Stage	Teacher Does Learning Experience (strategies/activities)	Student Does	3D Concept
EVALUATE Encourages students to assess their understanding and abilities and provide opportunities for teachers to evaluate student progress.	• Refers students to existing data and evidence and asks, "What do you already know? Why do you think . . . ?" • Observes students as they apply new concepts and skills • Assesses students' knowledge and/or skills • Looks for evidence that students have changed their thinking • Allows students to assess their learning and group process skills • Asks open-ended questions such as, "Why do you think . . . ? What evidence do you have? What do you know about the problem? How would you answer the question?"	• Checks for understanding among peers • Answers open-ended questions by using observations, evidence, and previously accepted explanation • Demonstrates an understanding or knowledge of the concept or skill • Evaluates his or her own progress and knowledge • Asks related questions that would encourage future investigations	Concept(s) students know or understand at any stage of the learning sequence where evaluation occurs

Source: Adapted from *Achieving Scientific Literacy: From Purposes to Practices* (Bybee, 1997).

Appendix E. Front Pages of a Sample NGSS Early Implementer Learning Sequence

Grade 4

Physical Science: Unit Overview and Learning Sequence Narrative

Introduction

The California K–8 NGSS Early Implementers Initiative, developed by the K–12 Alliance at WestEd with close collaborative input on its design and objectives from the State Board of Education, the California Department of Education, and Achieve, is a fast-start demonstration project to build local education agency (LEA) capacity to fully implement the Next Generation Science Standards (NGSS) as a core subject in the elementary grades (K–5) and as the State Board of Education's preferred integrated model in grades 6–8.

The four-year Initiative provides teachers and administrators with in-depth, content-rich professional development to build leadership capacity and teacher acumen to deliver high-quality three-dimensional learning for K–8 students. In addition, through collaborations among the K–12 Alliance, Achieve, and others, the LEAs in the Collaborative have opportunities to pilot test new NGSS-aligned tools, processes, assessment item prototypes, and digital and other instructional materials. The LEAs serve as resources for NGSS implementation across California, and in other NGSS-adopting states as well.

The resource in this appendix presents the conceptual storyline for a unit of instruction at a specific grade level, then focuses on a portion of the storyline called a learning sequence. The learning sequence uses the three dimensions of the NGSS — disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs) — to build and deepen student understanding of natural phenomena and design challenges.

Participants in the California NGSS K–8 Early Implementers Initiative developed and field tested the lessons in the learning sequence. The sequences were vetted by Achieve using the EQuiP tool and found to be aligned with the intent of the NGSS.

Unit Overview

The anchor phenomenon for this unit is: "Energy transfers in everyday life." This phenomenon is represented through explorations with Rube Goldberg machines in which objects move due to collisions and transfer of energy.

In this unit, students explore energy as it flows within and between systems identifying observable changes that occur, where the energy comes from and where the energy goes. Students investigate energy transfer from place to place and recognize that the faster a given object is moving the more energy it possesses. Students investigate energy transformation as the energy source is converted in its actions and apply their understanding by designing a device that transforms energy.

The Performance Expectation(s) addressed in this unit are:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Learning Sequence Narrative

The Learning Sequence Narrative briefly describes what students do in each lesson and links the learning between the lessons as a conceptual storyline. At the end of each learning sequence, students make connections to their understanding of the investigative phenomenon (and to the anchor phenomenon if appropriate).

The phenomenon for this NGSS Early Implementer Learning Sequence, entitled "Chain Reaction: Energy in Motion," is: Objects move in a Rube Goldberg machine. Students figure out this phenomenon by engaging with the following SEPs, DCIs, and CCCs:

- SEPs: Asking questions, planning and conducting investigations, constructing explanations and designing solutions
- DCIs: PS3. Energy; PS3.B Conservation of Energy and Energy Transfer; PS3.C Relationship Between Energy and Forces; PS3.D Energy in Chemical Processes and Everyday Life; ETS1.A Defining Engineering Problems
- CCCs: Energy and Matter; Systems and System Models, Cause and Effect

The following narrative is based on the conceptual flow found at the end of this section.

Lesson 1: "What's Going On?"

This lesson introduces the students to a phenomenon (chain reactions in a cartoon similar to a Rube Goldberg machine) https://media.rubegoldberg.com/site/wp-content/uploads/2016/06/Rube-Goldberg-Lesson-Plans.pdf to which they can anchor their learning. Students use their prior knowledge from kindergarten and 3rd grade about force and motion to observe and describe chain reactions in terms of: action (e.g., movement) and how the action occurred (e.g., forces). They explain their observations in terms of their prior knowledge about energy (DCI), cause and effect (CCC), as well as how they ask questions (SEP).

Lesson 2: "What is Energy and Where Does it Come From?"

In this lesson students explore sources of energy and how they use energy in their everyday lives. They learn about systems (CCC) in terms of their components and interactions. Students learn to draw a boundary (circle) around the components and begin to explore by carrying out an investigation (SEP) of how energy moves in and between systems. Throughout their exploration, students continue to think about: What is the system of interest? What observable changes are taking place? Where in the system are the changes occurring? Where does the energy come from? Where does the energy go?

Lesson 3: "Energy Transfers"

In this lesson, students conduct an investigation (SEP) to continue their exploration of how energy moves and formally label this movement as energy transfer. Students continue their exploration of how contact forces transfer energy between components within a system (CCC) and begin to explore interactions between systems which is a focus beginning in fifth grade. Students strengthen their investigations by having another opportunity to make observations to produce data as a basis for evidence to explain a phenomenon (SEP). Throughout their exploration, students continue to think about the questions from Lesson 2: What is the system of interest? What observable changes are taking place? Where in the system are the changes occurring? Where does the energy come from? Where does the energy go?

Lesson 4: "Collisions and Speed"

In prior lessons, students conducted investigations to observe how energy moves in a system — where it comes from and where it goes to. They learned the academic language of energy transfers. In this lesson, students use what they have seen energy do as it transfers and use that knowledge in an investigation (SEP) to define energy in terms of speed and collisions and their relationship (CCC).

Lesson 5: "Energy Transformation"

In this lesson, students test various devices (SEP) that convert a source energy into a different action (e.g, rubbing hands together producing heat and sound). Students identify the source of energy and the receiver of energy and continue to ponder the questions introduced in Lesson 2: What is the system of interest (CCC)? What observable changes are taking place? Where in the system are the changes occurring? Where does the energy come from? Where does the energy go?

Lesson 6: "DIY Machines"

In this last lesson of the unit, students apply their understanding of energy and its transfer/transformations in a design solution (SEP) to meet human needs. Students use the principles of engineering to design a Rube Goldberg machine that humorously solves a common classroom problem (CCC).

Learning Sequence 3D Progressions

DCI Progression

Lesson 1: Forces and collisions cause things to move (from K and 3rd grade). **Lesson 2:** Energy is present when there are moving objects. Energy has a source and causes an action that we use. **Lesson 3:** Energy can be moved from place to place by moving objects. Energy transfers in, within, and out of different systems. When objects collide, the contact forces transfer energy so as to change the object's motion. **Lesson 4:** Speed and collisions affect the transfer of energy. The faster an object is moving the more energy it possesses. In collisions some energy is typically transferred to the surrounding air; as a result the air gets heated and sound is produced. **Lesson 5:** Energy can be transferred from place to place by electric currents to produce motion, sound, heat, or light. A source of energy can be converted into different actions. **Lesson 6:** "Energy machines" can be designed to convert stored energy into a desired form for practical use.

SEP Progression

Note: If SEPs are emphasized in a lesson, they are in the foreground. If they support the learning but are not primary to it, they are in background.

Ask Questions: **Lesson 1:** Accessing prior knowledge from K–2 (ask questions based on observations to find more information about the natural world; ask questions that can be answered by an investigation). In **Lessons 2** and **3**, asking questions is a background (not foreground) practice. In **Lesson 4**, students ask questions to plan their investigation. They question what happens when a variable is changed and predict reasonable outcomes based on observed patterns (i.e., cause and effect relationships). In **Lesson 6**, students define a simple design problem that can be solved through the development of a tool that meets the criteria and constraints for the design.

Develop and Use Models: This practice is addressed as a background practice in **Lesson 6** where students develop a simple physical prototype to convey a proposed tool.

Plan and Conduct an Investigation: In **Lesson 2**, students build on their K–2 experiences of conducting an investigation to collaboratively produce data to serve as the basis for evidence to answer a question, to producing data to serve as the basis for evidence for an explanation of a phenomenon. In **Lesson 3**, students continue to use this practice as they did in Lesson 2. In **Lesson 4**, students continue to build their understanding of the practice including: using fair tests in which variables are controlled and the number of trials considered; making predictions about what would happen if a variable changed; and making observations to collect data that can be used as evidence to construct an explanation. In **Lesson 5**, students continue to make observations to produce data to serve as a basis for evidence of how energy is transferred. **In Lesson 6**, students use their observations to produce data to test a design solution.

Analyze and Interpret Data: In **Lesson 2**, students build on their K–2 abilities to record information to comparing and contrasting data collected by different groups to discuss similarities and differences in their findings. In **Lesson 4**, this practice is in the background of the lesson, not the foreground. In **Lesson 6**, students use data to evaluate and refine design solutions.

Construct an Explanation and Design Solutions: In **Lesson 4**, students use evidence (observations and patterns) to construct or support their explanations. In **Lesson 5**, students use their observations to find trends (patterns) in their data. They use these patterns to construct an explanation about energy transformation. In **Lesson 6**, students apply scientific ideas to solve design problems. They use evidence to design a solution to a problem and they compare solutions to a problem based on how well they meet the criteria and constraints of the design solution.

Argue from Evidence: In **Lesson 5**, this SEP plays a supporting role to constructing an explanation. Students support their argument (claim) with evidence and then compare and refine their argument based on an evaluation of the data presented.

Obtain, Evaluate, and Communicate Information: While this practice is not in the foreground of the learning sequence, it is in the background of most lessons where students are asked to communicate scientific information orally and/or in written format (mostly diagrams and charts).

CCC Progression

Patterns: Throughout the learning sequence, students use the same questions to debrief their learning from various explorations. The answers to these questions establish patterns in a variety of ways that can be used as evidence for their explanations.

Cause and Effect: In **Lesson 1**, students identify causal relationships and use these relationships to explain change. In **Lesson 4**, students identify causal relationships, speed, and energy, and use these relationships to explain the change (increased speed = increased energy). In **Lesson 5**, students use this crosscutting concept in understanding a variety of energy transformations. In **Lesson 6**, students test causal relationships as they design their Rube Goldberg machine and use those relationships to explain change.

Energy and Matter: Throughout the learning sequence, students focus on the element ″energy can be transferred in various ways and between objects.″ In **Lesson 2**, students recognize that energy transfers occur in most everything in everyday life. In **Lesson 3**, students recognize energy transfers in bowling systems and relate that to transfers in the Tom and Jerry cartoon. In **Lesson 4**, students use this crosscutting concept to explore the relationship between speed and energy in collisions. In **Lesson 5**, students continue to recognize that energy can be transferred in various ways and between objects. In **Lesson 6**, students design a Rube Goldberg machine using this crosscutting concept.

Systems and System Models: Throughout the learning sequence, students have various experiences with the element: "A system can be described in terms of its components and their interactions." **Lesson 1** assesses students' prior knowledge from K–2 (systems in the natural and designed world have parts that work together). In **Lesson 2**, students are introduced to a system as a group of related parts that make up a whole and they describe the system in terms of its components and their interactions. These two ideas are carried forward in Lessons 3, 4, and 5. In **Lesson 3**, students describe a bowling system as a group of related parts that make up a whole, that carry out functions its individual parts cannot, and that can be described in terms of its components and interactions. In **Lesson 4**, students describe the RGM system in terms of its components and interactions. In **Lesson 5**, students describe various energy transformations in terms of their components and interactions.

Appendix F. Norms for Collaborative Work

Establishing and adhering to group norms supports behaviors on the part of team members that facilitate constructive and productive group work. The K–12 Alliance uses the following norms (the "7 Ps," adapted from Garmston & Wellman, 1999) for collaborative work to foster cooperation and team building within the Early Implementers Core Leadership Teams:

Paraphrasing. Paraphrasing is one of the most valuable and least used communication tools in meetings. A paraphrase can be used effectively with a question. First paraphrase, then ask a question. Practice this skill and notice what happens to the dynamics of the conversation. Paraphrasing aligns the parties and creates a safe environment for thinking. Levels of paraphrase may include any of the following: clarify speaker statement, summarize hearing what was said, or shift what was said to include overarching purpose.

Pausing. Pausing is based on "wait time" research indicating that higher-level thinking takes three to five seconds and that allowing more time changes students' quality of thinking. Four kinds of pausing allow this kind of higher-level processing. The first type of pause is after a question is asked. The second is after someone speaks. A third is under the control of the speaker (e.g., "Give me a moment and I will answer"). The fourth is a collective pause formally structured by the group. Some pauses are decided by the group and some are initiated individually.

Probing for specificity. Human brains are not designed for specificity. Brains form quick generalizations from fragments of information. These quick judgments based on assumptions can cause difficulties in communication. Five areas contributing to overuse of generalizations are vague nouns and pronouns, vague action words, comparators, rule words, and universal quantifiers. Probing action asks members to remove the generalization and find the exact data.

Putting ideas on the table. Ideas are the heart of group work. In order to be effective, they must be released to the group (e.g., "Here is an idea for consideration" or "I am putting this idea on the table"). It is equally important to know when to remove an idea from the table. Use signal words such as "I think this idea is blocking our thinking" and "I want to remove it from the table" can be effective.

Paying attention to self and others. Meaningful dialogue and discussion is facilitated when each group member is conscious of oneself and others. This consciousness includes being aware of your own and others' posture, gesture, and other non-verbal cues. Paying attention to one's self and others could include monitoring the amount of talking and amount of silence or responding to others' learning style.

Posing questions. The balance of advocacy and inquiry requires both emotional and cognitive resources. The balance is most necessary at the exact point when many group members are least likely to want to inquire into the ideas of others. It is at the moment of greatest disagreement that this norm makes the biggest difference.

Presuming positive intent. Assuming that others' intentions are positive encourages honest conversations about important matters. Positive presuppositions reduce the possibility of the listener perceiving threats and challenges in a paraphrase or question. An example of this mindset is an overall faith in the other person to find his/her own solutions, thus eliminating the need for advice giving.

Appendix G. Reviewing Student Work During a TLC — Sample Rubric

Figure G1. Rubric for developing and using models

4	3	2	1
Model(s) in the response portray components accurately in a picture or diagram that relates to the claim in the explanation. Components are accurately labeled in the explanation.	Model(s) in the response portray components in a picture or diagram that relates to the claim in the explanation. Components are mostly labeled and accurate.	Model is incomplete (missing some components) or contains **minor** errors.	Model is missing, unclear, or contains major errors.
Relationships among those components are shown in the model AND described in the explanation.	Relationships among those components are shown in the model OR described in the explanation.	At least one relationship among those components is shown OR described.	No correct relationship(s) are identified.
The model can be used to provide an explanation AND a prediction related to the claim given that is grounded in science and includes meaningful limitations of the model.	The model can be used to provide an explanation OR a prediction related to the claim given that is grounded in science and includes meaningful limitations of the model.	The model can be used to provide an explanation and/or a prediction that demonstrates partial understanding of the science.	The model cannot be used to provide an explanation or a prediction.

4	3	2	1
The scientific reasoning **explicitly** uses the Crosscutting Concept of Cause and Effect as a **central frame** for the explanation.	The scientific reasoning **explicitly** uses the Crosscutting Concept of Cause and Effect in the explanation.	Appropriate Crosscutting Concept of Cause and Effect is **identified** in the explanation.	An appropriate Crosscutting Concept is not identified in the explanation.
The scientific reasoning is accurate, linking multiple lines of evidence to the foundational ideas in the science discipline(s).	The scientific reasoning is accurate, linking a few lines of evidence to the foundational ideas in the science discipline(s).	The scientific reasoning has minor errors. May or may not link the evidence to the foundational ideas in the science discipline(s).	The scientific reasoning has major errors or is missing.

Appendix H. Reviewing Student Work During a Professional Learning Community or Grade-Level Meeting: "Common" Student Work Protocol

This protocol would be used by a group of teachers looking at work that is comparable, or "common," because it was generated by students in classes following the same or similar lesson plans.

Time	NGSS Common Student Work Protocol Process (50 minutes)
2 min	**1. Getting Started Norms** • Remind participants: contribute descriptions, questions, and constructive comments about student work; maintain confidentiality about the work. • Explain that this process is about looking at student work, not about changing/rewriting the prompts. Looking at student work provides students and teachers with feedback for learning via next steps strategies for instruction and student learning.
3 min	**2. Review NGSS Learning Sequence Context and Goals** • Explain the focus target and the essential question that is being investigated concerning the student learning goals. • Explain the NGSS 3D context for this piece of student work. State disciplinary core idea, science and engineering practice, and crosscutting concept goal as appropriate.
15 min	**3. Review the Expected Student Responses for Science prompt** • Have participants reconnect with the prompts and previously generated "consensus" high-level performance response to the prompt.

Time	NGSS Common Student Work Protocol Process (50 minutes)
15 min	**4. Observe Student Work** • Determine the number of student work samples to analyze. Ask each team member to contribute to the "pile." • Holistically sort student work into piles that represent understanding of science: "Got it" or "did not get it." The "got it" grouping corresponds to the high-level performance response. • Sort the "did not get it" pile into three groups from minor errors, major errors, and extremely limited or no response. This grouping becomes the medium to low performance responses. • Discuss characteristics of each group. Add to chart in step 3.
10 min	**5. Infer/Next Steps** • What strategies or interventions might move students from one level to another? Discuss specifically for each level as time permits. • Discuss how these strategies will assist students/teachers with continued student learning of the selected practice.
5 min	**6. Debrief the Process** Ask participants to reflect on protocol process via the following prompts: • What are the benefits/challenges of using this process? • What are the benefits/challenges of using this process with your team? • How do you see students benefiting from the next steps strategies? • How will you continue the process?

Source: Adapted from *The Tuning Protocol* (McDonald & Allen, 2015) and *Using Data/Getting Results* (Love, 2002).

Appendix I. Reviewing Student Work During a Professional Learning Community or Grade-Level Meeting: "Un-Common" Student Work Protocol

This protocol would be used by a group of teachers looking at work that is not comparable, or "un-common," because it was generated by students in classes following different lesson plans.

Time	NGSS Uncommon Student Work Protocol Process* (50 minutes)
2 min	**1. Getting Started Norms (Facilitator)** • Remind participants: contribute descriptions, questions, and constructive comments about student work; maintain confidentiality about the work. • Explain that this process is about looking at student work, not about changing/rewriting the prompts.
3 min	**2. Set Context and Review NGSS Learning Sequence Goals (Presenter)** • Explain the focus target and the essential question that is being investigated concerning the student learning goals. • Explain the context for this piece of student work (where the work is situated in the instructional flow) and describe the NGSS 3D goal(s). • If appropriate, provide any special circumstances about the student work.
5 min	**3. Describe Task and Review Student Expected Responses (Presenter)** • Briefly describe the task/prompt. • Explain the expected student responses that include the full range of student response (i.e., high level of performance, medium level of performance, and a low level of performance).
10 min	**4. Describe the Student Work (Group only)** • What do you see? Group gathers as much information as possible from student work. • Holistically sort student work into piles that represent understanding of the NGSS learning goal: "Got it" and "did not get it." • The "got it" work should correspond with the high level of performance expected student response.

Time	NGSS Uncommon Student Work Protocol Process* (50 minutes)
10 min	**5. Interpret Student Work (Group only)** • From the student's perspective, what is the student working on? • Sort the "did not get it" pile into 3 groups: minor errors, major errors, and extremely limited or no response. The "did not get it" pile corresponds with the medium to low level performance responses. • Discuss characteristics of each group: What was the student thinking? Why were they thinking that way?
10 min	**6. Implications for Classroom Practice** • What strategies or interventions might move students from one level to another? Discuss specifically for each level as time permits.
5 min	**7. Reflection (Presenter)** • Presenter shares what they learned about the student work and what they are now thinking as their next steps.
5 min	**8. Debrief the Process** Ask participants to reflect on protocol process via the following prompts: • What are the benefits/challenges of using this process? • What are the benefits/challenges of using this process with your team?

Source: Adapted from *The Tuning Protocol* (McDonald & Allen, 2015) and *Using Data/Getting Results* (Love, 2002).

Appendix J. CA NGSS Early Implementers Initiative Science Walk-Through Tool

Early Implementers Walk-Through Tool: SCIENCE Instructional Core

Grade Level: _____________ **Walk-Through #** ____________

Task: What is the Focus Question? What question are students trying to answer or what problem are students trying to solve?	**Content: What are students learning?** What is the content? Is it aligned to grade level 3-dimensional learning?
Teacher: What is the teacher doing? How is instruction allowing all students to do the thinking and 3-dimensional learning? *(quantitative & qualitative evidence)*	**Students: What are students doing?** How are students interacting – with each other, the teacher, the task, and the 3 dimensions? *(quantitative & qualitative evidence)*

Developed by Oakland Unified School District in collaboration with NGSS Early Implementers Initiative, 2017.

Appendix K. Science Walk-Through Reflection Tool

Analyze, Reflect, and Narrow Focus

School/Team: ____

1. Analyze Data: What does the data say about student learning? Identify student strengths and challenges (just the facts) related to your goals.	2. Reflect on Practice: How did our practice impact student results?	3. Narrow Focus: Which narrow practice do we think would make the most impact in the next cycle? What is our Inquiry Question?
Priority Strengths:	**Root Causes of Strengths:**	**Practice**
Priority Challenges:	**Root Causes of Challenges:**	**What is your Inquiry Question?**

Developed by Oakland Unified School District in collaboration with NGSS Early Implementers Initiative, 2017.

Appendix L. CA NGSS Early Implementers Initiative: NGSS Evidence of Learning Protocol Matrix

The NGSS Evidence of Learning Protocol is a collaborative tool for teachers and administrators to identify the school's instructional implementation of the NGSS and identify PD support needs. The protocol features four elements to address the three-dimensional learning required by the NGSS:

1. Phenomena-based
2. Changes in Student Thinking about the 3 Dimensions (Science and Engineering Practices-SEPs; Crosscutting Concepts-CCCs; and the Disciplinary Core Ideas-DCIs)
3. Conceptual Coherence (learning sequence)
4. Connections to Common Core

The protocol is designed to capture teaching and learning at several intervals over time: a) how the learning is planned; b) how the learning is enacted during the lesson; and c) how the learning is assessed through student work representing student understanding of a partial or full performance expectation.

The protocol can be used by administrators and teachers, and/or for teacher collaboration.

For **the Element** that is chosen, the observer (administrator or teacher) will:

- meet with a teacher for 5–10 minutes to review the lesson **plan** that features the element,
- visit the classroom for 5–10 minutes to **observe** how the plan is **enacted** through teacher and student actions, and
- debrief with the teacher for 5–10 minutes after the lesson to **assess** through student artifact.

Figure L1. CA NGSS Early Implementers Initiative: NGSS Evidence of Learning Protocol Matrix

Estimated Time	Elements of Meaningful 3-Dimensional Learning in Science	Planned (Observe via planning documents)	Enacted (Observe the actions of the students and teacher)	Assessed (Observe through student work)
5 mins	Phenomenon(a) based (as defined by SEPs, DCIs, CCCs)	• Teacher selects appropriate phenomenon(a) for lessons, i.e., –phenomenon(a) meets the needs of and is relevant to learners *and* –phenomenon(a) has explanatory power	• Teacher provides content-rich experiences, (e.g., hands-on activities, video depiction, or simulation of the phenomena) • Teacher purposefully engages students in the phenomena through questioning, initial models, etc. (SEPs), CCCs or DCIs from prior knowledge/experience • Students engage in the phenomenon(a) through experiences that approximate the work of scientists and engineers • Students use the three dimensions to begin to make sense of the presented phenomena	Students: • Demonstrate an understanding of phenomena, (e.g., science notebook entry, diagram, science talk, or other evidence of student thinking) • Make connections between phenomena and everyday life

Estimated Time	Elements of Meaningful 3-Dimensional Learning in Science	Planned (Observe via planning documents)	Enacted (Observe the actions of the students and teacher)	Assessed (Observe through student work)
5 mins	Changes in Student Thinking (about the three dimensions)	Teacher designs: • A meaningful learning sequence that blends DCI(s), CCC(s), and SEP(s) to facilitate student sense making of the phenomena • Processes and strategies to access students' prior knowledge (e.g., DCIs, SEPs, CCCs) • Instruction that facilitates students' conceptual understanding of the three dimensions and provides for multiple practices (SEPs) that intertwine the DCIs and the CCCs for student sense making • Processes and strategies for student metacognition on their learning of the three dimensions	Teacher: • Provides a classroom environment that encourages student exploration and discourse • Provides experiences that deepen student understanding • Prompts critical thinking through questions about the connections of the three dimensions • Encourages students to challenge the thinking of other students • Provides time for students to explore and modify their thinking Students: • Develop and ask questions of the teacher and other students to modify their understanding of the three dimensions • Construct, refine, or edit explanations through additional experiences • Question the thinking of their peers, clarify own ideas, reasoning, and explanations • "Try out" their ideas in public (e.g., partners, small groups) • Make changes in their conceptual models as a result of new experiences and learning	Students: • Self-monitor and document their understanding of the three dimensions • Apply learning to a new situation within or beyond the classroom • Use multiple practices (SEP) and CCCs to make sense of phenomena • Use schema and metacognition to describe, discuss, and reflect on their understanding

Estimated Time	Elements of Meaningful 3-Dimensional Learning in Science	Planned (Observe via planning documents)	Enacted (Observe the actions of the students and teacher)	Assessed (Observe through student work)
	Conceptual Coherence (learning sequence)	Teacher: • Builds the learning sequence with a coherent storyline to foster conceptual understanding of the three dimensions • Focuses on the Performance Expectations (or a portion thereof) for their grade level • Accommodates the range of student conceptual understanding	Teacher: • Facilitates a learning sequence that features opportunities for students to build coherence, i.e., – Asks questions that connect to ideas in the storyline and move thinking forward consistent with the storyline – Uses student responses and actions to adjust the learning sequence to meet the range of student conceptual understanding Students: • Activate and use prior knowledge and experiences through written and oral activities to make predictions • Critically evaluate and question ideas, data, and possible explanations • Construct and revise evidence-based explanations • Engage in reflection and revision of their ideas and learning process	Students: • Articulate connections to demonstrate their new understandings of the three dimensions as featured in a partial or full Performance Expectation or storyline

Estimated Time	Elements of Meaningful 3-Dimensional Learning in Science	Planned (Observe via planning documents)	Enacted (Observe the actions of the students and teacher)	Assessed (Observe through student work)
	Connection to CA CCSS	Teacher: • Includes appropriate and integral connections among disciplinary content and practice standards in Mathematics and English Language Arts • Designs (as appropriate) connections with history and social science, other technical subjects, and other disciplines • Incorporates (as appropriate) strategies to support the needs of English learners based on the California ELD Standards	Teacher: • Provides for multiple authentic opportunities to apply CCSS and ELD standards in the context of science • Provides opportunities to connect with history and social science, other technical subjects, and other disciplines • Are engaged in discourse, writing, reading, and using mathematics to make sense of science Students: • Engage in student-to-student discourse that aligns with ELA/ELD collaborative interactions to gain an understanding of the phenomena • Write in science notebooks as a "thinking journal" to make connections between prior knowledge and the science concepts that explain the phenomena • Use Mathematical Practices and ELA Student Capacities when thinking and working in the science classroom	Students: • Use skills and knowledge of CA CCSS (e.g., science notebooks, problem solving, argumentative writing, primary sources, risk/benefit analysis) to demonstrate an understanding of three-dimensional learning

Glossary

Administrator Symposium — Annual regional event sponsored and delivered by BaySci, the K–12 Alliance, and California Science Project. Helps administrators in non-Early Implementers Initiative districts begin to plan NGSS implementation.

Anchoring Phenomenon — A phenomenon complex enough to be the focus of an instructional unit lasting multiple weeks or longer. Anchoring phenomena connect to the smaller, investigative phenomena that occur at multiple points throughout the unit of instruction.

Conceptual Flow — The name for both the process of mapping the storyline of three-dimensional (3D) NGSS instruction as well as the resulting graphic. A conceptual flow can be constructed for a six- to eight-week instructional unit or a year-long program, depending on the complexity of the anchoring phenomenon and how many of the grade-level performance expectations are incorporated.

Core Administrator — Administrator member of the Core Leadership Team. Provides professional learning to teachers and/or other administrators in the district.

Core Leadership Team (CLT) — Group of 3–5 administrators and 5–8 teachers established at each district at the beginning of the Initiative. The CLT meets with their Project Director regularly during each school year to plan and lead all Early Implementers Initiative activities. They meet with their K–12 Alliance Regional Director for six Technical Assistance Days each school year.

Core Teacher Leader — Teacher member of the Core Leadership Team. Provides professional learning to Teacher Leaders, other teachers, and/or administrators in their district or at project-wide events such as the Summer Institute.

CCCs (Crosscutting Concepts) — A way of linking the different domains of science. They include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change.[21]

DCIs (Disciplinary Core Ideas) — According to National Research Council's Framework for K–12 Science Education, disciplinary core ideas are the important concepts in each of four domains: physical sciences; life sciences; Earth and space sciences; and engineering, technology, and applications of science.

Expected Student Response — A step in the lesson planning process that entails identifying specific student outcomes and tailoring teacher behavior to elicit them.

Evidence of Learning Protocol — A three-part tool designed by the Early Implementers Initiative to foster and focus principal and/or teacher learning about NGSS instruction when observing science lessons. The ultimate goal of the Evidence of Learning protocol is to share the vision of NGSS instruction such that principals and

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[21] For more information on crosscutting concepts, see this website developed by an Early Implementer leader: https://crosscutsymbols.weebly.com/

administrators are better able to support teachers as they implement the new standards.

Instructional Unit — Three-dimensional (3D) NGSS phenomenon-based instruction lasting approximately six to eight weeks. Duration of an instructional unit can vary depending on the complexity of the anchoring phenomenon and the needs of the teachers involved in developing and teaching the unit. Often, instructional units are based on an anchoring phenomenon and as such would supply the framework for an entire conceptual flow.

Investigative Phenomenon — A phenomenon used as the focus of a learning sequence and helps students develop understanding of scientific concepts required to understand the larger, more complex anchoring phenomenon.

K–8 NGSS Early Implementers Initiative — Six-year Initiative (summer 2014 to spring 2020) supporting implementation of the NGSS by eight public school districts and two charter management organizations in California. Developed by the K–12 Alliance at WestEd in collaboration with the California State Board of Education, California Department of Education, and Achieve, the Early Implementers Initiative builds capacity of participating local education agencies to fully implement the NGSS in grades K–8.

The K–12 Alliance — A WestEd program of science education leaders and professional learning providers who plan and deliver all project-wide activities for the Early Implementers Initiative.

Learning Sequence — Three-dimensional (3D) NGSS phenomenon-based instruction lasting several lessons. A learning sequence is based on an investigative phenomenon and represents part of a conceptual flow. Learning sequences can be designed using the "5E" instructional model.

Lesson — Three-dimensional (3D) NGSS phenomenon-based instruction lasting for a single class period, typically 45 to 90 minutes, but potentially longer.

Phenomena — Natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict.[22] There are two types of phenomena, anchoring and investigative.

Principal Academy — For principals of every Teacher Leader. Delivered by the Early Implementers Initiative leaders (Regional Directors and Project Directors) to foster understanding of the shifts in teacher practice required to implement the NGSS in the classroom.

Professional Learning — Contemporary terminology for professional development that emphasizes interactive learning strategies rather than rote learning techniques where information is delivered to relatively passive listeners.

Professional Learning Community (PLC) — Regular teacher-led meetings for professional development on topics of their choice. Used by the Early Implementer teachers when possible to share knowledge.

Project Director — District person responsible for leading all Early Implementers Initiative activities for the district and representing the district at monthly Initiative-wide planning meetings with Regional Directors.

Questioning Strategies — Strategies used by teachers to prompt students to discuss and make sense of scientific concepts and phenomena.

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[22] See: https://www.nextgenscience.org/resources/phenomena

Regional Director — Member of WestEd's K–12 Alliance staff assigned to provide leadership and support to one or two Early Implementers Initiative districts and to meet at monthly Initiative-wide planning meetings with Project Directors.

SEPs (Science and Engineering Practices) — 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. They include asking questions (for science) and defining problems (for engineering); developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations (for science) and designing solutions (for engineering); engaging in argument from evidence; obtaining, evaluating, and communicating information.

Summer Institute — Weeklong professional learning event held every summer to kick off the new Early Implementer school year. Attended by all Initiative participants, some as leaders (Regional Directors, Project Directors, Core Leadership Team members) and others as learners (Teacher Leaders).

Teacher Leader (TL) — One of 30–70 teachers in each district who joined the Early Implementers Initiative in Year 2, one year after the Core Teacher Leaders. Teacher Leaders attend annual Summer Institutes and participate in two TLCs each school year, one in the fall and one in the spring, and other district-level professional learning.

Teaching Learning Collaborative (TLC) — Lesson study activity brings together three to four same-grade Early Implementers Initiative teachers from different schools within the district. Teachers plan and teach a lesson to two classrooms of students. Each Teacher Leader participates in two Teaching Learning Collaboratives per year.

Technical Assistance Day — Meeting of the Core Leadership Team, facilitated by the K–12 Alliance Regional Project Director, to plan NGSS implementation in the district. Six days per school year.

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Next Generation Science Standards in Practice

Tools and Processes Used by the California NGSS Early Implementers