SEPTEMBER 2020 | EVALUATION REPORT #13

NGSS in the Classroom: What Early Implementer Science Instruction Looks Like

Katy Nilsen, Ashley Iveland, Burr Tyler, Ted Britton, Kimberly Nguyen, Elizabeth Arnett

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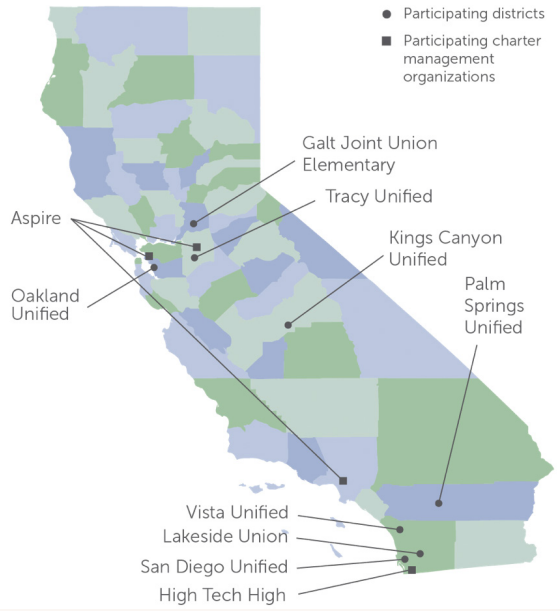
NGSS EARLY IMPLEMENTERS

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). The progress, experiences, and lessons of the NGSS Early Implementers, as they are called, can inform others implementing the NGSS. The 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. Funding for the Early Implementers Initiative (the Initiative) is provided by the S. D. Bechtel, Jr. Foundation, and the Hastings/Quillin Fund is supporting participation by the charter organizations.

The Initiative spans 2014 through 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 three NGSS 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 composed 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 multiyear initiative and access evaluation findings as well as instructional resources at k12alliance.org/ca-ngss.php.

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- *The Needle Is Moving in California K–8 Science: Integration with English Language Arts, Integration of the Sciences, and Returning Science as a K–8 Core Subject* (Evaluation Report #1, October 2016)
- *The Synergy of Science and English Language Arts: Means and Mutual Benefits of Integration* (Evaluation Report #2, October 2017)
- *Administrators Matter in NGSS Implementation: How School and District Leaders Are Making Science Happen* (Evaluation Report #3, November 2017)
- *Developing District Plans for NGSS Implementation: Preventing Detours and Finding Express Lanes on the Journey to Implement the New Science Standards* (Evaluation Report #4, February 2018)
- *Next Generation Science Standards in Practice: Tools and Processes Used by the California NGSS Early Implementers* (May 2018)
- *Making Middle School Science Whole: Transitioning to an Integrated Approach to Science Instruction* (Evaluation Report #5, October 2018)
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- *Investing in Science Teacher Leadership: Strategies and Impacts in the NGSS Early Implementers Initiative* (Evaluation Report #7, February 2019)
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- *It's About TIME: A Rigorous New Process for Selecting Instructional Materials for Science* (Evaluation Report #11, April 2020)
- *Six years of scaling up districtwide implementations of the Next Generation Science Standards* (Evaluation Report #12, August 2020)

Executive Summary

This 13th report in WestEd's evaluation of the K–8 Early Implementers Initiative for the Next Generation Science Standards (NGSS) provides an extensive response to the following question: What does NGSS teaching look like in the classroom? The report also briefly describes specific ways that teachers have advanced in their NGSS teaching over the years of the Initiative and how the Initiative prepared them for such teaching.

The report draws most strongly from more than 50 classroom observations of, and interviews with, 24 teachers across six districts. It is also informed by multiple interviews with each district Project Director as well as results of an annual survey with high response rates from more than 500 K–8 science teachers.

NGSS in Action

The report examines how teachers regularly teach the NGSS core content in ways that address the following key features of NGSS teaching:

- **Equity:** Engaging all students
- **3D learning:** Blending all three dimensions of the NGSS (i.e., disciplinary core ideas, science and engineering practices, and crosscutting concepts)
- **Engineering and science phenomena:** Using real-world scientific phenomena and/or engineering problems to launch and drive instructional lessons and units
- **Student agency:** Having students do investigations in ways that give them the responsibility and opportunity for learning

The report first discusses Initiative teachers' experiences with instructional practices that promote equity and access. Then, through six vignettes of lessons observed by the evaluators, the report illustrates how teachers at both the elementary and middle grades addressed the three other NGSS features listed above. Each vignette is followed by commentary explaining how key features of the NGSS were incorporated into the lesson. We have tried to describe NGSS teaching in enough detail to help administrators and policymakers recognize when they are seeing NGSS-based instruction and when they aren't.

The first two vignettes of a couple of grade 8 science teachers in the same school both include student investigation of how light bends (refracts) when traveling through water. However, one teacher's instruction addresses NGSS features, such as using a real-world phenomenon to engage students (solving challenges in studying sharks), while the other uses more traditional science instructional methods. Evidence of NGSS features in the two lessons are contrasted in detail.

The next four vignettes were selected to showcase each of the four noted NGSS features: 3D learning, phenomena-based instruction, engineering, and student agency.

Advances in NGSS Over Time

Survey and interview data indicated that sustained, multiyear professional learning was both needed and productive. That is, Initiative teacher leaders grew in their implementation of NGSS teaching over time as they participated in formal professional learning each year.

How the Initiative Prepared Teachers for NGSS Teaching

This section briefly describes the professional learning and support provided to teachers by the Initiative and then focuses on the evaluation's final spring 2020 survey in which teacher leaders were asked which specific activities and project participants had the most impact on their science instruction.

Teacher leaders noted that other teacher leaders in the Initiative, the district Project Director, and school administrators had notable impacts on empowering their NGSS teaching. They also noted that the following activities impacted their NGSS teaching: participating in professional learning communities, engaging in independent research/learning, and interacting informally with other teachers outside the Initiative (beyond the formal professional learning opportunities).

Recommendations for How Administrators Can Support NGSS Teaching

The report concludes with the following recommendations for how administrators can support teachers in implementing NGSS teaching:

- Understand that teachers need extensive professional learning about NGSS instruction.
- Know that the classroom may seem "messy" or "chaotic" during NGSS instruction.
- Keep in mind that NGSS instruction takes ample classroom time.
- Realize that you may not see all three dimensions of the NGSS in a single class period.
- Support and encourage teachers to incorporate engineering in their NGSS instruction.
- Provide teachers with professional learning on how to incorporate student agency and equity in their NGSS teaching.

Introduction

In a meeting about the Next Generation Science Standards (NGSS) Early Implementers Initiative, Michael Kirst — president of the California State Board of Education at the time — remarked, "As someone not in the classroom day to day, I really want this evaluation to show me what NGSS teaching looks like. I think other policymakers and district and school administrators also are puzzled about this because these standards are such a big change."

Indeed, the NGSS instructional approach described in the opening quote from a grade 1 teacher is quite a departure from how many people previously regarded science teaching. In classrooms carrying out high-quality NGSS teaching and learning, students are doing authentic investigations of their own science questions about phenomena in their world instead of just hearing about science facts. They are engaged in hands-on science activities primarily to learn science and engineering practices like those used by scientists. Students are collaboratively carrying out their investigations with other students. The teacher guides and probes rather than being a sage on the stage.

This 13th report in WestEd's evaluation series of the NGSS Early Implementers Initiative is focused foremost on describing what NGSS teaching looks like. The report describes in some detail a variety of science and engineering lessons observed across grades K–8 and explains how each lesson addresses key features of the NGSS. The report's concluding Recommendations section summarizes key considerations for supporting high-quality NGSS instruction.

> When students have time to observe and collect data, while being able to talk to a partner or their table groups, it allows them to follow their curiosity and together solve their questions … Giving students plenty of time to make their observations, with some guiding questions when necessary, allows them to direct their own learning.
>
> *—Grade 1 teacher*

We have tried to give enough detail about NGSS teaching to enable administrators and policymakers to recognize when they are seeing NGSS-based instruction and when they aren't. However, we did not aim to provide the level of detail that teachers might seek to craft lessons similar to those in this report because teachers are not an intended primary audience for this report.

As secondary emphases, the report describes ways that teachers have advanced in their NGSS teaching over the years of the Initiative. We also briefly describe how the Initiative prepared teachers for NGSS teaching. Our discussion of preparing teachers is brief because prior evaluation reports have been devoted to describing the Initiative's professional learning offerings and supports.[1]

1 See evaluation reports #7, *Investing in science teacher leadership: Strategies and impacts in the NGSS Early Implementers Initiative* (https://www.wested.org/resources/investing-in-science-teacher-leadership-ngss-early-implementers/), and #8, *Collaborative lesson studies: Powerful professional learning for implementing the Next Generation Science Standards* (https://www.wested.org/resources/powerful-professional-learning-for-implementing-the-next-generation-science-standards/).

This report draws most strongly from multiple observations of and interviews with 24 teachers across six districts and an annual survey with high response rates from more than 500 K–8 science teachers who participated in the Initiative. Two to four interviews with all district Project Directors each year also inform the findings. The Appendix contains more details about the evaluation methods.

The Call for NGSS Teaching

More than 70 percent of the nation's students are now learning science that is based on the NGSS to varying extents (National Science Teaching Association, 2020), with California being among the first states to adopt and begin implementing the standards widely (in 2013). At their core, these standards call for teachers to provide instruction that addresses and blends all three of the NGSS "dimensions," as displayed in the center of Figure 1 (Iveland, Nilsen, & Boxerman, 2019). Such **3D instruction**, or treatment of the three dimensions, involves students learning the following core content:

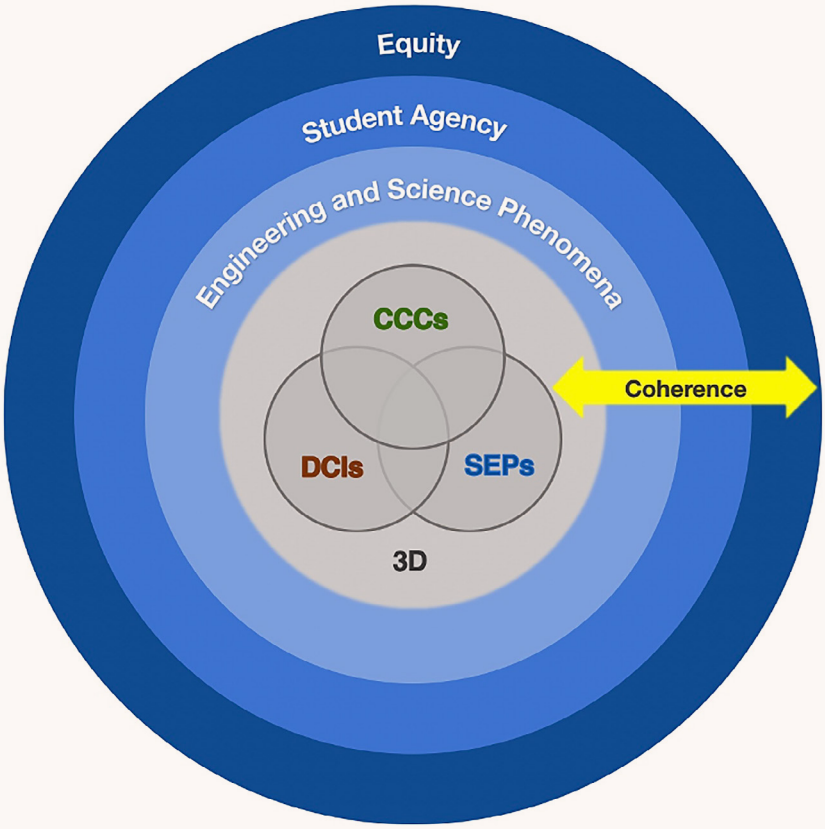
- Disciplinary core ideas (DCIs)
- Science and engineering practices (SEPs)
- Crosscutting concepts (CCCs) across science topics or disciplines

Any and all of this NGSS core content should be taught in ways that address the following features of the NGSS (Figure 1 depicts these features as surrounding the NGSS core content):

- **Engineering and science phenomena:** Using real-world scientific phenomena and/or engineering problems to launch and drive instructional lessons and units
- **Student agency:** Having students investigate these phenomena or problems in ways that give them the responsibility for learning instead of being told what to do by the teacher
- **Equity:** Engaging all students in the science investigation
- In California, there is an additional feature expected for NGSS teaching in middle school — integration of the sciences, as called for by the California preferred integrated model of science instruction. Integration of science disciplines (e.g., life sciences, Earth and space sciences, physical sciences) should be applied in both the construction of 3D lessons and in selecting appropriate phenomena or engineering challenges for science instruction. However, this NGSS teaching feature is not explicitly addressed in this report because a prior evaluation report was devoted to it.[2]

2 See evaluation report #5, *Making middle school science whole: Transitioning to an integrated approach to science instruction*, https://www.wested.org/resources/making-middle-school-science-whole/.

Figure 1. NGSS enactment model



NGSS in Action: Features of High-Quality NGSS Instruction

In Year 3 of the Initiative (2016–17), 24 teachers were recruited to be "case study" teachers[3] who would provide an evaluation of the NGSS with a classroom-teacher perspective. Each year, these teachers were observed teaching one or two class periods of NGSS science.

Vignettes of high-quality NGSS instruction from case study teacher classrooms are presented in this section to illustrate four specific features of NGSS instruction:

- 3D learning
- Engineering
- Phenomena-based instruction
- Student agency

It is important to note that the NGSS do not call for all of these features to be present in a single lesson, or even in a single unit. This report presents lesson examples for each feature to provide rich illustrations of how they looked in the classroom.

Science Instructional Practices That Promote Equity and Access

Before diving into vignettes of classroom instruction, we want to describe equity,[4] an overarching feature of the NGSS that should be incorporated into all lessons. The NGSS explicitly assert that providing high-quality science instruction to all students is an issue of equity. The NGSS were developed to make science learning accessible to students with a wide range of experiences and abilities. In fact, all four of the key NGSS features listed previously contribute to that goal. Several additional aspects of the NGSS that further support a commitment to traditionally underserved students are explained below.

Learning science supports language development. For years, many students have been denied access to science in order to receive extra instructional time in English language and math. However, research has shown, and Early Implementer teachers attest, that the NGSS

3 Case study teachers were nominated by district Project Directors as teacher leaders who were making some of the most substantial changes in their NGSS teaching. Over four years, there was some turnover and attrition in this group of teachers. In Year 6 (2019–20), 11 teachers from six districts were observed.

4 Appendix D of the NGSS treats this topic in detail. *"All standards all students": Making the Next Generation Science Standards accessible to all students*, https://www.nap.edu/read/18290/chapter/10.

improve language skills.[5] A case study teacher provided this anecdote to illustrate the value of relevant NGSS learning experiences for her English language learners:

> *This year I had two students who were beginner English language learners... We were doing an activity [about] how to explain a weather hazard.... These two little boys were just so into the activity that even though one of them was very reluctant to speak English, [they both] explained their design to me. Both of them were very successful in explaining, mostly in English, how their model had worked. (Grade 3 case study teacher)*

Learning in science is a journey. One of the biggest and most important shifts called for by the NGSS is moving from students learning facts and information to students gaining skills that enable them to take responsibility for their own learning (i.e., student agency, one of the features of NGSS instruction). The goal is no longer for students to just remember information, but to interact with the science, starting where they are. Because "the correct answer" is not the focus of instruction, what each student brings to the experience, and where they are in their progress, is not judged. As one teacher said, "There are no wrong answers when we're exploring." Another teacher put it this way:

> *As they go through the process [of more NGSS learning], ... they'll be a lot more willing to disagree with somebody and they'll be a lot more willing to give any answers they know might be wrong because of how we respected [sharing ideas] in class. It's like, okay, well that answer is wrong, but being wrong gives us a whole other set of data that we didn't have before. Right answers or wrong answers can help us, and so they definitely got more brave ... definitely more confident, and a lot more willing to try things they haven't tried before because they know that it's okay to fail. If they fail, or are not successful, that's just part of science. (Grade 8 case study teacher)*

Focusing on science in students' lives and cultures engages them. Another aspect of the NGSS that supports learning by historically underperforming students is the emphasis on cultural relevance. Culture influences all facets of learning; learners who find the learning environment confusing, unwelcoming, or unsupportive will be at a disadvantage. When teachers plan instruction around phenomena that reflect what students experience in their local environment, those experiences serve as a base upon which meaningful and memorable academic learning can be built.

Evaluators have heard from the vast majority of Early Implementers, both teachers and administrators, that NGSS teaching has been effectively reaching students who were previously unengaged.[6] Many teachers expressed that their traditionally underserved and unengaged students were experiencing success in science and that, in

5 For more information on language development through NGSS instruction, see evaluation report #2, *The synergy of science and English language arts: Means and mutual benefits of integration*, https://www.wested.org/resources/synergy-of-science-and-english-language-arts/.

6 For a detailed report on the impact of NGSS teaching on students, see evaluation report #2, *Engaged and learning science: How students benefit from Next Generation Science Standards teaching*, https://www.wested.org/resources/engaged-and-learning-science/.

fact, they were often the ones to offer the most creative ideas in class.

Having varied ways to learn science provides more access points. To meet the different needs of students, a classroom with effective NGSS teaching and learning provides a variety of structures for communicating and multiple modes of learning. Students formulate their conceptual understanding by talking to partners; engaging in teacher-led, whole-class discussions, student-to-student sharing, and questioning of ideas; and recording thoughts in their notebooks. In interviews, teacher leaders said that students had more access points and opportunities to express understanding compared to learning other subjects:

> *The NGSS were engaging for the kids and made them want to pay attention and be part of the lessons. So I think that that was a positive thing for those students that, while when math and language arts would come up and they wouldn't feel like they had a lot to contribute in some cases, with science, they felt they could — at least to draw about it, write about it in their notebooks, because their notebooks were for them, or to even just participate and observe the experiment in action. (Grade 4 case study teacher)*

> *I do have one little boy that sticks out in my mind for this year ... his whole academic career he hasn't been able to progress a lot.... Anyway, this year whenever we would do anything with science or engineering, he would be a lot more engaged because it was a lot more about doing and talking and comparing.... At the beginning of the school year he spent most of the day with his head down on his desk. But once he was engaged and he had to do a report on the polar bear, he was really interested. And you could see that he was gaining a lot from it and he was feeling so much more positive about his achievement. He felt like he could do something that the other kids were doing. Whereas, in the past, he'd always felt like he couldn't do it because he couldn't read or he couldn't do his math or he couldn't write. (Grade 3 case study teacher)*

> *One of my English language learners just lit up. He completely made the connection and was able to verbalize the science on the quiz and when we were having a discussion. That was an aha for me, for him to be able to do that.... And he's low. He's going to be tested for special education. I just thought, 'Wow, he made that connection pretty quickly.' I think just because there were so many visuals, and hands-on [activities], and things that he could make those connections with, and all those learning modalities.... Because he was using the vocabulary. That was really cool. That stands out because this kid is really low. He has behavior problems. That this little face lit up. It was really nice to see that. (Grade 4 case study teacher)*

Similarly, a district Project Director explained that the science and engineering practice "developing and using models" is particularly valuable for historically underserved students:

> *I think developing and using models was a way to engage students and allow them to show their thinking in a more creative way that wasn't a part of how we did school in the past. And it was valid. You can draw and show your thinking, and that's okay. That's actually encouraged. (District Project Director)*

One middle school case study teacher worked at an alternative school and taught students across multiple grade levels. In this nontraditional setting, an evaluator observed how the teacher's NGSS instruction engaged these students in science and engineering. The projects they designed and constructed were well-planned and original, and the testing of them was an event to which the community was invited. The overall experience was clearly meaningful for the class.

The previous explanations provide global statements about NGSS instruction. The following lessons describe what evaluators observed in the classroom. First, two lessons are presented to contrast different pedagogical approaches to addressing similar content; then, a lesson is provided to illustrate each of the four key features of the NGSS.

A Tale of Two Lessons

The following two lessons, taught by two grade 8 teachers, were observed at the same school. The lessons addressed similar physical science content. However, the teachers used starkly different instructional practices that reflect differing alignment with the features of the NGSS. Lesson #1, observed over two days, is part of a multilesson learning sequence; lesson #2 is essentially a stand-alone lesson developed and assigned to an Early Implementer teacher by a department head who had not participated in Early Implementer professional learning. After the two lessons are presented and discussed, features of the NGSS in the two lessons are contrasted.

Lesson #1: Understanding White Sharks

When she first introduced it weeks ago, Ms. Gill (pseudonym) grounded the multiweek white shark unit[7] in an engaging and **locally relevant anchor phenomenon:**[8] a map showing an increase in shark encounters in recent years, especially in Southern California, where the class was held (see Figure 2). The teacher used this phenomenon to kick off a series of activities that would result in students gaining a deep understanding of many aspects of the phenomenon, including how scientists are learning about it.

Through some initial research and investigation into what they wondered about white shark sightings and attacks in the state, students had already begun learning about how scientists research and monitor white sharks and what kinds of technology they use to do this. On the day they learned about the REMUS SharkCam, which, according to one student, "is like a submarine that floats around in the water, finds sharks, and documents shark activity," the teacher explained to students that they would be **designing** and **engineering** an improved REMUS (or SharkCam):

7 The shark unit was an NGSS-aligned and Achieve-vetted unit developed by the K–12 Alliance (Achieve, 2020). For the full grade 8 learning sequence, and learning sequences for other grades as they become available, see https://k12alliance.org/ca-ngss.php.

8 Bolded terms indicate instructional features or practices consistent with the NGSS. See the Glossary for further explanation of *anchor phenomena*.

> *The original design of the REMUS made the sharks attack it; so, your job as a shark researcher is to design a better REMUS so you can observe their behavior, not just their aggressive feeding behavior of them attacking it.*

On the day of the classroom observation, the lesson kicked off with an **investigative phenomenon:** a video showing scientists as they attempted to attach satellite tracking tags to the fins of white sharks as part of their research on shark movement and behavior. The scientists were having trouble seeing the sharks clearly when looking down into the water from above. The video explained that certain parts of a shark must be avoided when attaching a tracker, which made the scientists' task even more difficult.

Students discussed their ideas about the scientists' challenge, and the class used an inflatable shark in the classroom to discuss where on the shark they thought scientists should attach the tracker. Then Ms. Gill asked them to draw or write a **model of their thinking** about the challenge, with "concise bullets describing what you think light does" when it hits water, "like what you saw in the video of scientists tagging the sharks." She gave students a choice on what this model would show: "You guys can decide what you do with this model. You just need to **make your thinking visible**."

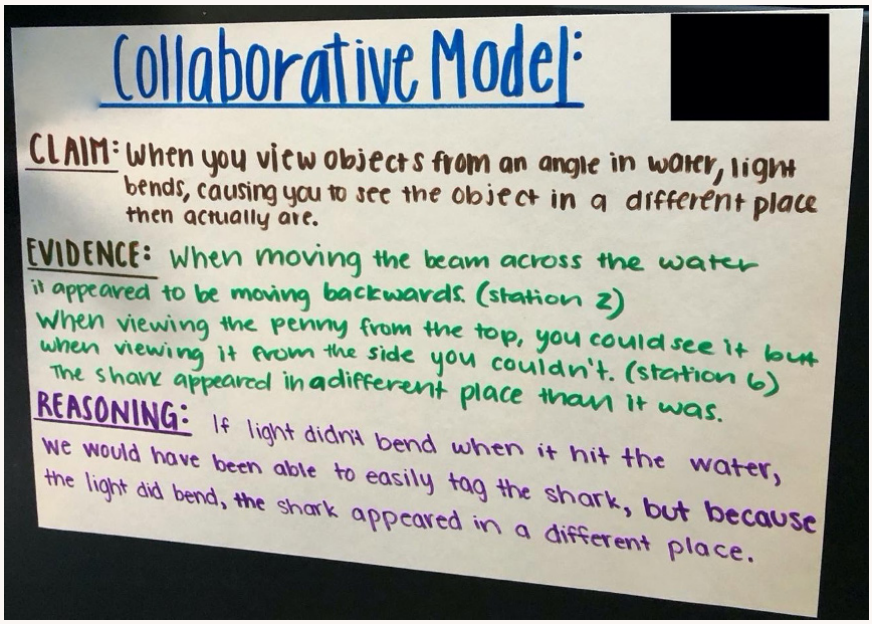
Next, Ms. Gill set up a series of lab stations in the classroom that provided materials for students to conduct **hands-on investigations** into different properties of light. At one station, students could use a long dowel to simulate attaching a tracker to a small submerged shark toy. They remarked that the activity was "pretty hard to do." Students found that they often missed the target on the shark's body that they had agreed was the best location for the tracker because "[the light interacting with the water] makes it look like [the dowel] is bending."

The following day, in small groups, students used evidence from these investigations, along with information they had known or learned previously, to complete two group assignments: 1) a collaborative explanation using **Claim, Evidence, Reasoning (CER) statements** (see Figure 3) and 2) a model (see Figure 4). In both assignments, students worked in teams to express what they thought was happening that made it difficult to tag the sharks when viewing them from above the water.

Figure 2. Shark wall display

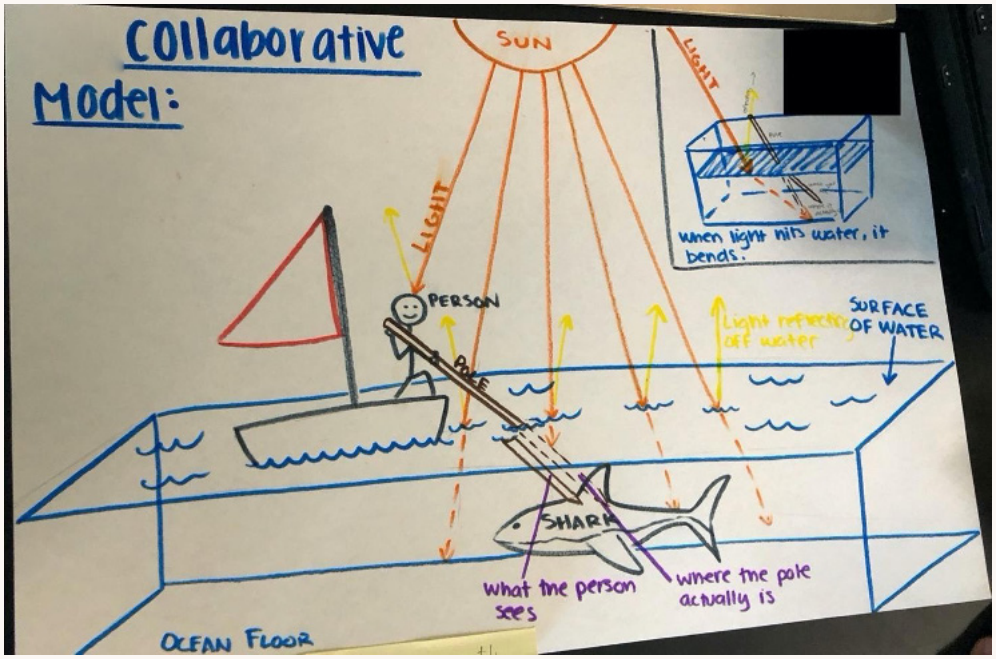
Students in Ms. Gill's class were used to seeing these signs at local beaches.
Source: Classroom observation conducted by evaluator.

Figure 3. One team's Claim, Evidence, Reasoning statement



Source: Classroom observation conducted by evaluator.

Figure 4. Team model of light refraction



Source: Classroom observation conducted by evaluator.

In subsequent lessons, students worked toward understanding how researchers learn about white sharks, designing a better REMUS SharkCam, and understanding the impact that humans have on the marine environment of the white shark.

Commentary

Ms. Gill **engaged her students authentically as scientists and engineers**. First, she used a **locally relevant anchor phenomenon** (the increase in shark encounters in recent years) to engage students' interest. Because the phenomenon was locally relevant, most or all of the students likely had some **prior knowledge** about it, providing a base to which new learning could adhere. Subsequent lessons were linked to this phenomenon and provided students with a context that made learning more meaningful. That is, they had a reason to pay attention because they knew that it would be helpful for them to understand how and why light interacts with water when it came time for them to try to solve a problem through an **engineering** project. **Students were active participants in class, pursuing their own questions and project ideas.** Three-dimensional instruction is evident in Ms. Gill's shark unit. Students **developed and used models** and **carried out investigations**, which are two science and engineering practices. They also learned about **energy and matter**, a crosscutting concept, and they explored physical science related to the path that light travels.[9]

There are also aspects of **instructional practice that promote access and equity** in this vignette: Ms. Gill regularly referred to visuals and models around her classroom, including an inflatable shark model in her room that was used to make the discussion about shark anatomy more concrete and relatable for all students. Students worked through the stations on properties of light in **small groups**, enabling **student-to-student discourse** in which they could ask and answer questions of each other. They learned about properties of light through **hands-on investigations** that enabled them to experiment. Finally, the topic of shark encounters was **locally relevant** and likely familiar and personally meaningful to most, if not all, students because they live in a beach community where residents are generally aware of these dangers.

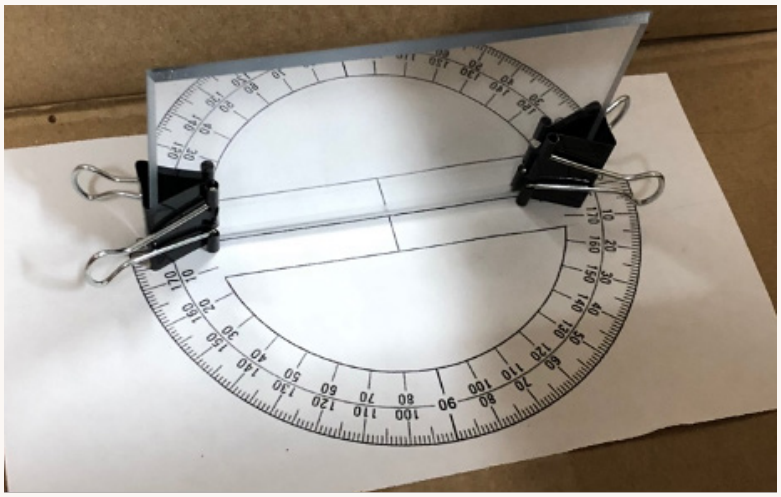
Lesson #2: Understanding Light

During a science lesson, Ms. Lumen (pseudonym) was teaching her grade 8 students about properties of light. She had set up a series of lab stations around the room for students to **investigate** how light waves interact with various materials. Each station had step-by-step instructions telling students what to do.

When students had different answers about the angles that the light reflected at one of the stations, the **teacher explained through a demonstration** of the lab on the overhead projector that if their mirror was not exactly parallel to their protractor, the laser would not bounce off the center of the protractor, leading to consistently inaccurate measurements (see Figure 5).

9 This is an example of Next Generation Science Standard DCI MS-PS4-2: https://www.nextgenscience.org/dci-arrangement/ms-ps4-waves-and-their-applications-technologies-information-transfer.

Figure 5. Reflected light station setup

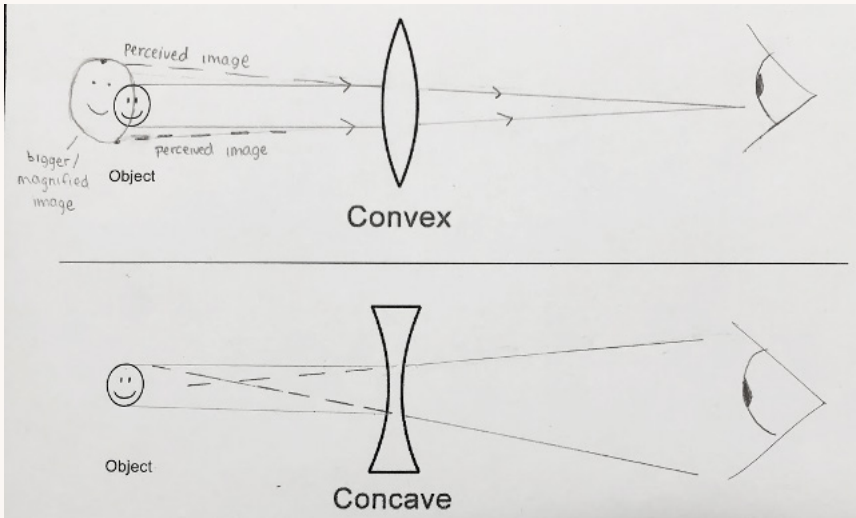


Source: Classroom observation conducted by evaluator.

After students had experienced the investigations, Ms. Lumen reconvened the class. With a worksheet on the overhead projector, she questioned students on what they saw at the refracted, absorbed, and reflected light stations. Then Ms. Lumen drew models of what they should have seen at the stations. While the students did these investigations themselves, the teacher brought them together to come to the correct answer that she added to the projected worksheet.

Next, students were instructed to summarize their results from each test in their worksheets and develop **models** for what happened in the experiments (see Figure 6).

Figure 6. Sample of student model (copied from teacher model)



A few students shared their answers, and one student in particular received praise from the teacher for providing multiple answers: "You guys are lucky to have [student] in your class because she **gives you all the answers**." The teacher asked the class to try and come up with "one rule for light" to put in the conclusions section of their worksheets. Several students contributed responses, and the teacher wrote them down on the overhead. The teacher asked if they all agreed with everything said so far, and some **students seemed hesitant to offer their ideas**.

Commentary

Ms. Lumen did not anchor the lesson in a phenomenon. By requiring students to follow steps prescribed by the teacher rather than allowing students to figure out the steps on their own, the activity was not personally relevant or meaningful to the students. The lesson included no activity or context that required students to apply the science they were learning to the real world. Furthermore, by **demonstrating one of the labs** to show why student answers were inconsistent, Ms. Lumen did not give students an opportunity to determine on their own where they had made a mistake; this limited their opportunity for agency. By filling out worksheets with answers provided by the teacher and listening to the teacher's explanations, the entire class may not have truly understood what was being asked for or done in the lesson. Because **Ms. Lumen provided the correct answers to students, and she drew the model** on the overhead projector that she ultimately wanted from students, she didn't provide flexibility in how students might interpret the science they were learning. This deprived her of the opportunity to see students' thinking, which could potentially reveal misconceptions and guide next steps to meet her students' needs. In this example of science instruction, most of the time, students were passive recipients of information instead of active learners taking ownership of their own learning and were therefore **deprived of epistemic agency**.

It is important to note that while this teacher received training in the NGSS from the Initiative, she was teaching a lesson that had been developed by a science teacher who had not received any Initiative-led professional learning.

These two lessons addressed some of the same content, but they differed considerably in pedagogy. Table 1 summarizes how NGSS instructional practices were or were not used in the two featured vignettes.

Table 1. Evidence of features of the NGSS in the shark and light vignettes

Features of the NGSS	Shark vignette	Light vignette
Phenomena-based instruction	Learning was anchored in an engaging and relevant phenomenon on sharks. Students explored different investigative phenomena through lab activities to determine what was happening with light.	There was no incorporation of a phenomenon. The teacher did not draw on students' lived experiences during the lesson.
3D learning	Students developed models (i.e., one of the NGSS dimensions) to show their understanding of how and why light bends when it hits the water. Students' models were original because they were given choice in how to construct these models.	Students developed models for what happened with the lenses and the light that they saw in their investigations. Most students copied down what the teacher wrote and drew on the overhead.
Engineering	Not observed, but a culminating piece of the shark unit that the observed lesson was part of was an engineering activity to optimize the design of the REMUS SharkCam.	There was no incorporation of engineering.
Student agency	Students developed collaborative and original models about light and decided which evidence from their investigations to use in the model. Students used sense-making and scientific discourse as they engaged in group lab investigations. Students revised their models as their conceptual understanding progressed. Working in small groups to process what they had learned provided students reluctant to speak in front of the class a chance to share their ideas.	Students followed step-by-step lab procedures provided by the teacher. Only some students shared their ideas during whole-class activities and many copied what the teacher wrote on the overhead projector in their worksheets and in their models. The teacher did not create space for every student to engage and contribute. She singled out one student for praise, which implied lack of trust in the ability of the other students.

The following sections further explore the four key features of the NGSS and describe pieces of lessons based on observations of classroom teaching and teacher interviews.

Phenomena-Based Instruction

Phenomena are observable events that occur in the universe and cause us to wonder. We can use our science knowledge to explain or predict them. Learning to explain phenomena is one of the central reasons that students engage in the three dimensions of the NGSS.[10]

Lesson #3: What Is Killing the Sunflowers?

Mr. Flor (pseudonym) began his grade 4 science lesson by showing the class a picture of dead sunflowers, the phenomenon for the lesson sequence. Students shared what they **noticed** and **wondered** about the photo. Many wondered how the plants died. Then students discussed what they knew about plants and what they would like to learn about plants. They talked about plant structures and how plants grow:

> ***Student 1: I know plants grow from seeds, but how did the very first seed begin?***
>
> ***Student 2: I know plants are in different shapes and sizes.***
>
> ***Student 3: I know plants can help us and the environment. I want to know how long they can go without water.***
>
> ***Student 4: How much water does an average plant need?***

Next, Mr. Flor asked students to share with a partner **what they know about pollution** and to come up with some examples. After some students shared their ideas with the whole class, the teacher provided the following scenario: A new company that makes pesticides has moved into a city. He asked students to use their knowledge of plants, especially plant structures and their functions, to provide evidence for or to disprove a claim that the company might be responsible for the plants dying.

Students drew and labeled parts of a flower in their notebooks and then hypothesized why the plants might be dying. After students shared their ideas, they were given supplies to **plan and carry out an investigation** in which they gather evidence that the plants were dying because of the chemicals in the water. Mr. Flor gave students cups of water, food coloring, and white flowers and pointed out that the food coloring represented the pesticide chemicals in the water. He provided no more direction than that. During the investigation, students made **predictions, based on their current evidence,** of what they thought would happen to the flowers. During the investigations, they planned and talked with each other and the evaluator as they made sense of what they were observing with the flowers, food coloring, and water.

10 For detailed information about Early Implementer tools and processes related to choosing and incorporating phenomena in science instruction, see special evaluation report, *Next Generation Science Standards in practice: Tools and processes used by the California NGSS Early Implementers*, https://www.wested.org/resources/next-generation-science-standards-in-practice/.

At one table, a student asked the other three: "What's your design?"

> *Student 1: I say put water in the cup, add food coloring and then the flower, and I think the flower will die because of the chemicals and food coloring.*
>
> *Student 2: That's what I think too.*

At another table, the group replaced the colored water in one cup with clear water. They wanted to see what would happen. When asked if that was a change in plan, they said yes.

> *Teacher: What do you think will happen?*
>
> *Student: The clear-water flower will live and the other will die.*

The lesson concluded with students **reflecting** on the activity in their notebooks. Each student **drew a model** of what they predicted would happen with their flowers and answered two questions: "How will your experiment provide evidence that the pesticide company is or is not at fault?" and "How do plant structures function to cause a plant to be polluted by groundwater?" The next day, the students checked their flowers to see what had happened. If the white flowers had been placed stem-down into the colored water, they turned the color of the water. Students realized that the stem could allow the food coloring (or pesticides) to go up into the flower itself and actually change it. This helped them understand how chemicals in groundwater could affect plants.

Commentary

Mr. Flor used an **anchor phenomenon** of dead sunflowers to spark students' curiosity and **cause them to wonder**, "Why are the plants dying?" Students then **designed investigations** to engage in sense-making to understand some of the reasons why the sunflowers might have died. As students explored with the provided materials, they noticed how plant structures, like stems, might affect how pesticides are taken up into flowers. The investigations that students engaged in allowed them to figure out the science, which helped them to construct explanations about the anchor **phenomenon**.

In interviews, case study teachers talked about the value of using phenomena to drive instruction. One grade 5 teacher explained that all of her instruction included phenomena and that she liked that teachers can learn alongside students when seeking answers to explain phenomena. "Everything we've done has been a phenomenon that [the students] investigate and learn about and question.... It might be a unique phenomenon that I don't know much about yet, but that's the great thing about it: We're learning together," she said.

Another teacher, who also said she consistently tied her instruction to phenomena, described how phenomena can be big or small, local or more generalizable. The key is that phenomena cause students to be intrigued:

> *I think it's a great way to engage the students ... It doesn't have to be something that the kids are actually touching.... The anchor phenomena can be a big thing that affects you like, 'Why is [our city] so windy at times and calm at other times?' Even something small that the kids can see and that they can have some sort of.... attachment to, or that they really feel affects their life or they're intrigued by. (Grade 3 case study teacher)*

In their final interviews, case study teachers said they were very comfortable with phenomena-based instruction. Eight out of 11 teachers said that they used phenomena at least 90 percent of the time to drive their science instruction.

3D Learning

The NGSS include three dimensions: disciplinary core ideas (what scientists know), crosscutting concepts (how scientists make connections among the sciences), and science and engineering practices (what scientists and engineers do and how scientific knowledge develops). A teacher may not address all three dimensions in a single class period, but all three dimensions come together in a complete NGSS lesson, which may take multiple class periods.

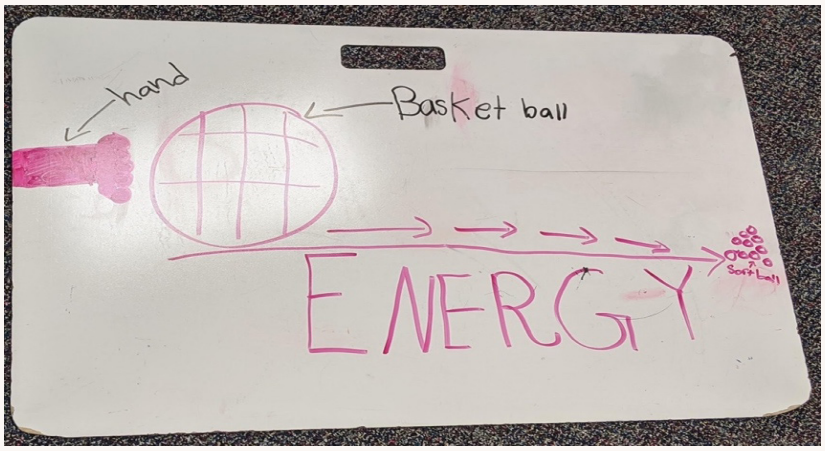
Lesson #4: Making Models of Energy

Grade 4 teacher Ms. Rollins had her students design a **system to model the transfer of energy** through collision. When introducing the activity on the first day of this two-day observation, she gave students a choice of materials to use to show energy transfer.

> *Teacher: We're going to do an exploration to see if we can use stuff around the school and classroom and show energy transfer with it. In a system of your choosing … I have some items — basketballs, tennis balls, dodgeballs, and, if you'd like to go smaller, here's a box of cars, wooden balls, golf balls, softballs, frisbees, more cars. Okay, we have to make a model of what we'd like to use and how we want to use those things to* ***create a system where energy is transferred****. Look at the monitor for what we'll do next. You're going to come up with a plan for how you're going to show energy transfer.*

Students individually planned their designs, then got into teams of three, chose a design or combined aspects of their designs, and drew a **model** of their system on a whiteboard (see Figure 7). Then they tested their system (see Figure 8). They videotaped a test in slow motion, and each team presented to the class what they had done. In the presentations, they showed their videos, described their system, and talked about where the **energy** originated, what **caused** the transfer of energy, and where the energy was transferred to. Each member of the team participated in the presentations, and other students asked questions of team members after each presentation.

Figure 7. Model and testing of team designs



Source: Classroom observation conducted by evaluator.

Figure 8. Testing team designs

Source: Classroom observation conducted by evaluator.

The next day, students rewatched all the videos. Ms. Rollins facilitated a whole-class discussion around the following questions: "What was the same about all the energy transfer **systems**?" and "What was different?" Students noted that all the videos showed a collision that **caused energy to transfer** from one object to another.

Commentary

These two consecutive lessons explicitly incorporated at least two crosscutting concepts (i.e., **systems** and system models and **energy** and matter) and two science and engineering practices (i.e., developing and using **models** and planning and carrying out **investigations**). The disciplinary

core idea was **energy transfer.**[11] The lesson is also a strong example of student agency: Students planned their own investigations, worked together to come up with their own energy-transfer examples, and discussed with and asked each other questions about their results.

Engineering

In the NGSS classroom, students learn about science concepts while applying the engineering design process to solve problems. The process consists of six steps: design, build, test, evaluate, revise, and retest. Students begin by applying their prior knowledge to design a solution to a problem. Through building and testing their design, they collect evidence, which is used to revise both their understanding of the underlying science and their design.

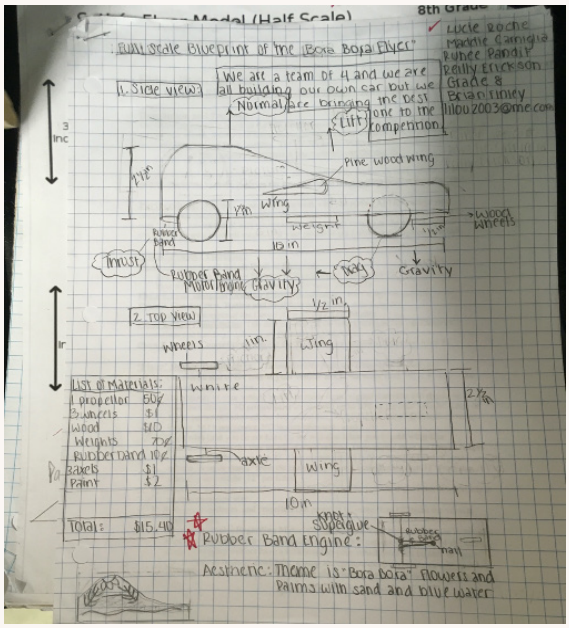
Lesson #5: Designing Flying Cars

Grade 8 teacher Mr. Aero (pseudonym) taught his students physics through **engineering**. His class participated in a "Fly Your Ride" competition, where students built and "flew" vehicles that launched down a ramp and jumped a gap. The flying car project involved four phases:

- Design, in which students researched and drew sketches of project ideas (see Figure 9)
- Construction, testing, and modifications, in which students constructed prototypes of their devices (see Figure 10) and engaged in testing and modification cycles
- Class competition, in which students competed with their peers in science class
- County competition, in which students competed against students from other schools during an event held at a local museum

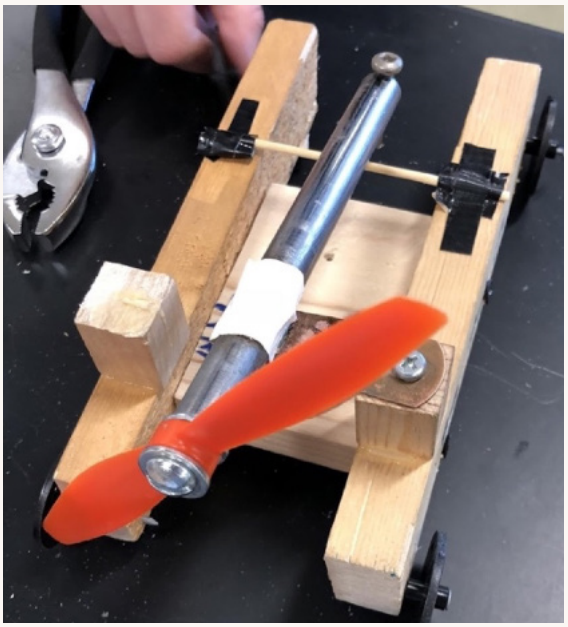
11 This is an example of Next Generation Science Standard PS3.B: https://www.nextgenscience.org/dci-arrangement/4-ps3-energy.

Figure 9. Blueprint of team designs



Source: Classroom observation conducted by evaluator.

Figure 10. Prototype of team design



Source: Classroom observation conducted by evaluator.

Students were given constraints they needed to consider, including the overall size of their vehicle, the types of materials that were permissible, and the size and types of protrusions allowed (i.e., winglike protrusions, balloons, parachutes, and propellers). Students were also given blueprint criteria, including neatness, size, title, heading, and drawing specifications (e.g., side-view versus top-view and labels).

Commentary

Some engineering-based units are driven by phenomena that present a problem for students to solve (e.g., a polluted lake, a need to move a heavy object). This unit does not have a phenomenon, but it is a robust **engineering** design challenge that addresses a problem: We need to make a car that flies. To carry out the challenge to design and build a flying car, students had to research and apply their understanding of physical science concepts. They also used science and engineering practices (e.g., obtaining and evaluating information, analyzing and interpreting data) and crosscutting concepts (e.g., structure and function, energy and matter). Students conducted **all stages of the engineering design process**: design, build, test, evaluate, revise, retest. Evaluators noted that both boys and girls were highly engaged and that their flying car designs were very creative.

Student Agency

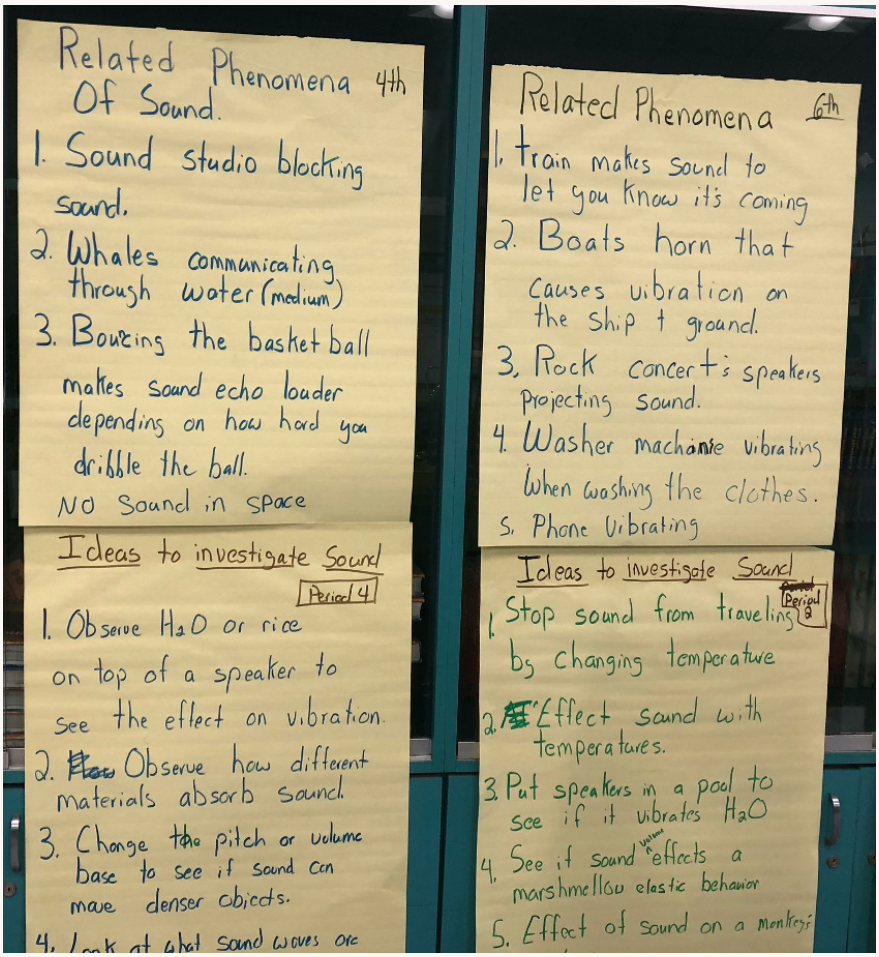
Lesson #6: Students Figuring Out Sound Student Agency

Mr. Peal, a grade 8 teacher, has been exploring sound waves with all of his classes. The walls of his classroom hold artifacts from class discussions (see Figure 11). Students have brainstormed their own sound-related phenomena and ideas

for investigating sound, and there are posters of detailed models titled, "How can sound make something move?" In addition, one wall, labeled "Driving Questions Board," was covered in questions that students had written on sticky notes. The questions were separated into three columns: Sound Source, Sound Traveling, and Sound Receiver. There were more than 60 questions posted.

Part of the observed lesson was based on one of these student questions. The class had been using a drum to examine sound vibrations. Mr. Peal let the class know that the question he was about to ask them to think about came from a student: "Is it louder up here (holding the drum up in the air) or on a solid surface?" The class discussed their predictions. The teacher asked, "How can we collect evidence to answer this question?" Because there was only one drum, the teacher demonstrated the students' suggested investigations.

Figure 11. Brainstorm of sound-related phenomena and investigations from teacher's fourth-period and sixth-period classes



Source: Classroom observation conducted by evaluator.

Mr. Peal asked another question of the class: "Turn and talk — would you expect any object that makes sounds to move in the same way we saw the musical instruments and speaker move? Why or why not?"

Some students talked, but not all. One student offered, "It depends on the material and if it is hollow or not, also the intensity."

> *Student 1: I did my own investigation [with my voice]. When you whisper it doesn't vibrate anymore.*
>
> *Teacher: I heard you say it depends on the material, what it is made out of. That relates to some of our questions on the Driving Questions Board. Good thinking.*
>
> *Student 2: I agree because it really depends on what the object is, and what it's made out of.*
>
> *Student 3: I have a question. A higher sound, does it make [the vibration] more condensed?*
>
> *Teacher: That's a good idea. We can test it on Monday. I didn't bring a speaker today. But you came up with a really good question.*

Commentary

This lesson illustrates one way that students have agency in the NGSS classroom. Mr. Peal clearly made a point of **leveraging student questions to drive instruction**:

He planned part of a lesson around a student's question.

He planned a new investigation based on a student's question.

When a student's comment related to questions and wonderings that the class recorded on the Driving Questions Board, the teacher directed the students back to their own science ideas.

Throughout the lesson, the teacher encouraged **student inquiry**. Sometimes, the inquiry directed what the whole class did and other times, students engaged in their own individual investigations. For example, a student made a comment related to intensity and drew from her own investigations with sound: "I did my own investigation; when you whisper, it doesn't vibrate anymore."

The teacher consistently encouraged students to explore, to think about things on their own, and to share ideas and evidence with one another rather than rely on him to provide the "correct" answers or steps to follow. In other words, he encouraged them to behave like scientists.

When asked how they promote student agency in their classrooms, case study teachers described a range of strategies that support students working like scientists, including promoting curiosity about phenomena; fostering student ability to generate relevant and, ultimately, testable questions; leveraging student questions to drive instruction; fostering students' ability to consider what else needs to be investigated; encouraging student questioning and sharing of ideas with one another; and facilitating student sense-making versus providing quick and easy answers.

> *We definitely have our lessons already laid out, but we try to incorporate student inquiry in the lesson. So we always open up with asking them their questions, their thoughts, their wonderings. Questions and wonderings, and we always chart*

that. And then we kind of take their questions and try to guide them toward something that we want them to focus on. Then, instead of just saying, 'Next we're doing reading,' we'll ask, 'Okay, so what are some other ways we can find out about the beaver's structure and function? We did some video. What else?' And then they raise their hands and everyone says, 'Pictures and books and things.' And then we say, 'Oh great, that's perfect because next we're going to read a book.' It makes them feel like they are also helping to drive the instruction. (Grade 1 case study teacher)

I think understanding the 5E lesson format[12] and [the principles in] how people learn[13] has been really freeing for me [and helped me use student inquiry to drive instruction]. I have been able to take a step back as the expert in the classroom in terms of the content. And I can frame it for them so that they can find their information. (Grade 5 case study teacher)

And with the inquiry, a lot of times if we watched videos, they had to at least give me a few questions. They'd write them down and then tell me or put it on a sticky note and then we would always refer back as we did each phase of the lesson. We refer back to their questions and say, 'Are you still wondering this? Does it make you wonder anything more? Or do you feel you know enough to answer your own question now?' (Grade 5 case study teacher)

This teacher described the impact on her class:

Discourse, not just teacher-to-student but student-to-student. The whole growth mindset of failure, that is a part of it. That has really, really changed. They're not afraid. They welcome that and they realize they learn from that. What else? Just the environment of the room and the kids, and the respect with each other as scientists. (Grade 4 case study teacher)

In final interviews with the case study teachers, they were asked how often their instruction is student-driven rather than teacher-directed. Responses ranged from "not very often" to "every lesson."[14] Teachers mentioned making instruction more student-driven through practices like notebooking, questioning strategies, hands-on learning, incorporating student questions, and engineering design.

12 According to the 5E instructional model, originally developed by Biological Sciences Curriculum Study (BSCS; Bybee et al, 2006) and commonly modeled by the Early Implementers, the five stages of a lesson are engage, explore, explain, elaborate/extend, evaluate.

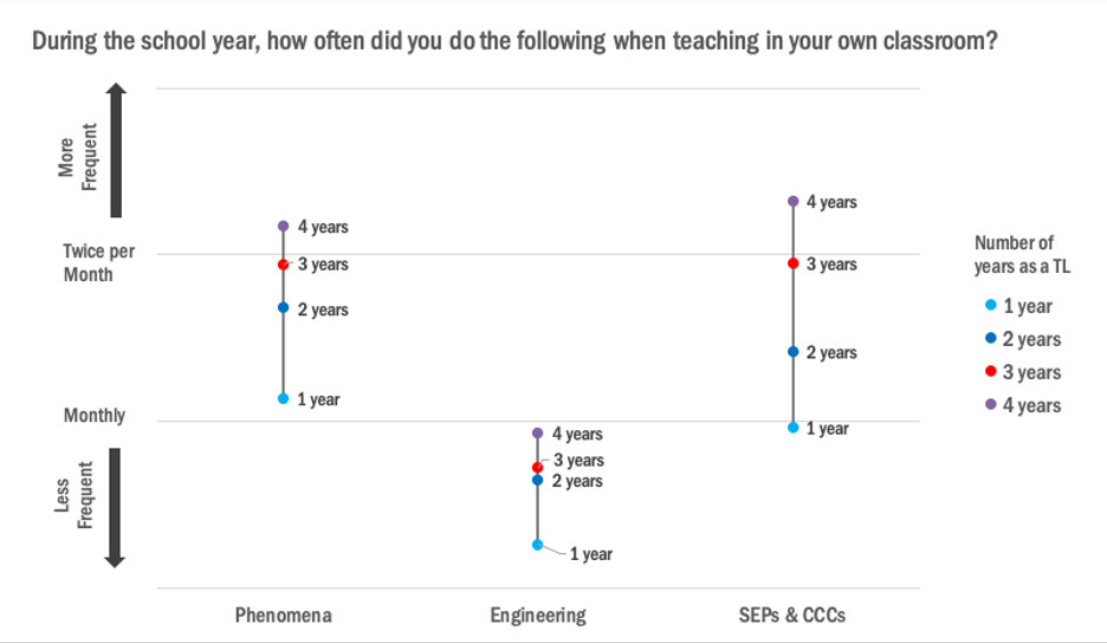
13 National Research Council. 2000. *How people learn: Brain, mind, experience, and school: Expanded edition*. Washington, D.C. The National Academies Press.

14 Because this was asked in the late spring of 2020 after schools were closed, case study teachers were difficult to contact. Of the nine who were interviewed, two reported "not often"; three reported "50–60 percent of the time"; one reported "weekly"; and three reported "a lot/every lesson/95 percent of the time."

Advances in NGSS Over Time

When looking at teacher leaders' implementation of key features of the NGSS by the end of the Initiative (the 2019–20 school year), survey results indicated that, overall, those with more years of experience in the Initiative as either Teacher Leaders or Core Teacher Leaders[15] reported incorporating phenomena, the SEPs, and the CCCs into their science instruction slightly more each year (see Figure 12). These survey findings point to the value of providing intensive and sustained professional learning to teachers implementing the NGSS.

Figure 12. Teacher leader implementation of key NGSS features increased steadily from 2015–16 to 2018–19



Source: 2018–19 Early Implementers Spring Survey (N=309).
Note: Data are weighted means combined for Core Teacher Leaders and Teacher Leaders.

15 In this report, "Core Teacher Leaders" is used to refer to the teachers who joined the Initiative the first year (i.e., the summer of 2014) as part of a district Core Leadership Team. "Teacher Leaders" (uppercase) is used to specifically refer to the group of 30–70 teachers per district who joined the Initiative in the beginning of the second year (i.e., the summer of 2015). When referring to both Core Teacher Leaders and Teacher Leaders together, this report uses "teacher leaders" (lowercase). Case study teachers, whose instruction was featured in the "NGSS in Action" section of this report, were both Core Teacher Leaders and Teacher Leaders.

As teacher leaders continued to grow in their mastery of the NGSS, they expanded the reach of the Initiative by sharing their expertise with non-Early Implementer teachers (called "expansion teachers") in their districts and schools. This was the intention of the leadership structure and training provided to teacher leaders — that by the end of the Initiative, all K–8 teachers of science would be implementing the NGSS to some extent.

In interviews at the end of the Initiative (i.e., during the spring of 2020), Project Directors were asked if there were any features of NGSS teaching that **all** teachers in their district had mastered. They talked about how teachers used phenomena to drive instruction:

> *Phenomena, understanding phenomena. That's going to come through essential questions, because they try to ... It's all about the big questions. Some of them were good at that before NGSS, but now they've kind of wrapped their head around, 'Oh, but the phenomena come first, and then your questions.' (District Project Director)*

However, Project Directors had mixed opinions about whether teachers were equipped to let student questions drive the learning taking place in the classroom:

> *All teachers, I would say, they are getting much closer to the idea of student-centered understanding and using phenomena and student questions about phenomena to try and drive the instruction; they do that to varying degrees, but I think they're making huge leaps in that. (District Project Director)*

> *The inquiry is very difficult because it means letting kids be at the center, and their questions at the center, and not being the one who is the one who knows everything. That's, I think, more of a struggle and continues to be. (District Project Director)*

Two Project Directors also mentioned that the practice of allowing students to figure things out and engage in discourse was also being utilized in English language arts or math in their districts:

> *I think there is a lot, there is a movement at least toward letting kids figure out things because that's the same way our new math program is. So the teachers are getting better at that productive struggle kind of thing in math. And that's something that they're starting to understand in the science. 'Oh, we don't tell them at first. Oh, we want them to figure something out.' That's one thing that they're really starting to grasp as a whole. (District Project Director)*

> *They've really grown in terms of promoting student discourse.... Notebooking and student discourse I think are the two that I most frequently see done better than they've been done in the past. (District Project Director)*

How the Initiative Prepared Teachers for NGSS Teaching

The previous examples of NGSS teaching were drawn from case study teachers, Core Teacher Leaders, and Teacher Leaders who received intensive professional learning and support on NGSS implementation over a period of up to four years.[16] Teacher Leaders attended annual week-long Summer Institutes and also participated in a Teaching Learning Collaborative (TLC),[17] the Initiative's version of lesson study, once per semester. Core Teacher Leaders received this same professional learning, and more; they also participated in centralized four-day leadership institutes twice per year and in technical assistance meetings with their district Project Director and designated Regional Director from WestEd's K–12 Alliance six times per year.

During these professional learning activities, teacher leaders learned about NGSS content and pedagogical shifts. They also participated in leadership development. As teacher leaders gained familiarity with the NGSS, many of them were tasked with providing professional learning in different capacities (e.g., leading Summer Institute sessions, facilitating TLCs, planning and delivering district- and school-level professional learning to peers, organizing family science nights, and providing leadership in their professional learning communities and grade-level teams).

Impact of Professional Learning

In the 2020 Early Implementers Spring Survey, teacher leaders were asked how much impact certain types of **activities** had on their science instruction. They reported that interacting with other teachers (outside of formal professional learning events) had the greatest impact. Informal sharing of resources and collaboration between teachers have been a key tenet of the Initiative, where teacher leaders took on roles in their schools and districts as NGSS ambassadors were tasked with supporting other teachers in their NGSS implementation.

Teacher leaders reported that participation in a professional learning community and independent research/learning were the second and third most impactful activities, respectively. Further, in their final interviews, several case study teachers discussed the Early Implementers Initiative more broadly as being impactful or referenced specific

16 For a full description of the professional learning provided by the Initiative to teacher leaders, see evaluation report #7, *Investing in science teacher leadership: Strategies and impacts in the NGSS Early Implementers Initiative*, https://www.wested.org/resources/investing-in-science-teacher-leadership-ngss-early-implementers/.

17 For the full story of TLCs, see evaluation report #8, *Collaborative lesson studies: Powerful professional learning for implementing the Next Generation Science Standards*, https://www.wested.org/resources/powerful-professional-learning-for-implementing-the-next-generation-science-standards/.

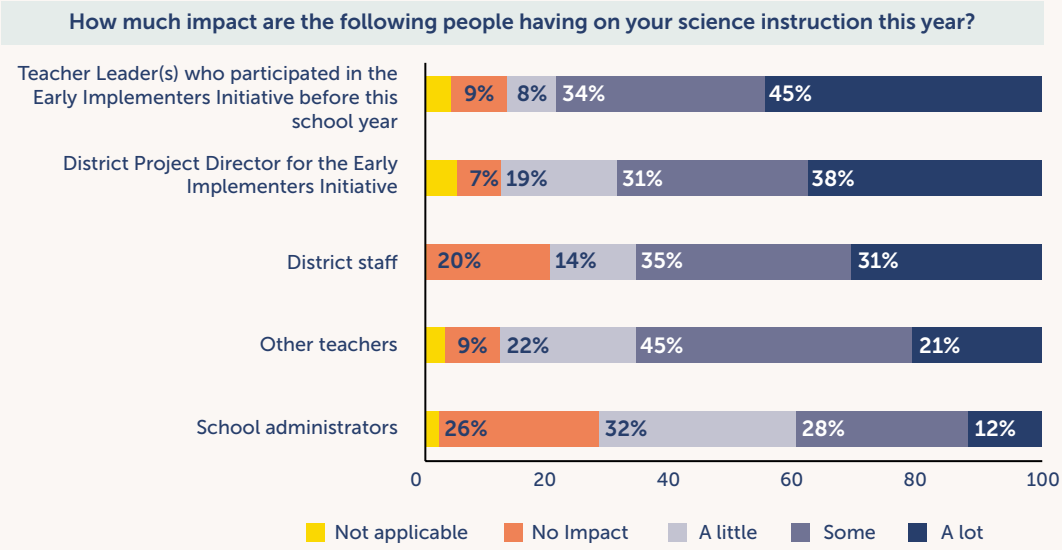
activities (e.g., Summer Institutes, leadership meetings, TLCs). One case study teacher even stated the following:

> *I really think I owe my whole career to Early Implementers. Because I would not be where I am today. I just know 100 percent I would not be. (Grade 8 case study teacher)*

Figure 13 illustrates that nearly half of Core Teacher Leaders indicated that their district's Project Director and other Teacher Leaders had "a lot" of impact on their teaching. In comparison, more than one-third of Teacher Leaders reported that the Project Director and other Teacher Leaders had "a lot" of impact.

It is notable that a majority of teacher leaders indicated that school administrators had at least "a little" impact on their science instruction. It is challenging for administrators to have the opportunity and knowledge to directly impact teachers' instruction in a specific school subject because they support all subjects. The Initiative spent an exceptional amount of attention on providing professional learning and support to administrators about NGSS teaching.[18] Survey data show that almost three-fourths of Teacher Leaders (73 percent) and two-thirds of Core Teacher Leaders (67 percent) indicated that their school administrators impacted their science instruction to some extent (combining values for "A little," "Some," and "A lot").

Figure 13. Impacts on teacher leaders' science instruction



Source: Early Implementers Spring Survey, administered by WestEd in 2020 (N=108; 31 Core Teacher Leaders and 77 Teacher Leaders).

18 For a full description of the professional learning provided by the Initiative to administrators, see evaluation report #10, *Administrators matter in NGSS implementation: Updated findings on how school and district leaders are making science happen*, https://www.wested.org/resources/administrators-matter-in-ngss-implementation-2019/.

Recommendations

Administrators and other education leaders should consider the following recommendations in order to effectively support high-quality NGSS instruction:

Understand that teachers need extensive professional learning to implement NGSS instruction. Gaining a thorough knowledge of key features of the standards is not possible for teachers in a single year (or even two, three, or four years). Only through trying to implement the NGSS over time (and experiencing failure along the way) will teachers gain confidence and proficiency with this kind of instruction. Providing opportunities for teachers to collaborate and compare notes during this process will accelerate their ability and willingness to experiment and advance.

Know that the classroom may seem "messy" or "chaotic" during NGSS instruction. Teachers need to know that it is okay to experiment when transitioning to the NGSS.

Keep in mind that NGSS instruction takes ample classroom time. Figuring out rich science phenomena and solving complex engineering problems can take many weeks, and many wrong directions may be tested to get to an answer or solution that works. Rest assured that this is not time wasted — students are most certainly learning important aspects of the three NGSS dimensions through this process.

Realize that you may not see all three dimensions of the NGSS in a single class period. It is possible that teachers can only focus on one or two dimensions of the NGSS at a time, and they will add other dimensions at other moments. Most important is that all three dimensions come together in an entire lesson, which may take multiple class periods. A complete unit of instruction, comprising multiple lessons, should incorporate several disciplinary core ideas, several science and engineering practices, and several crosscutting concepts.

Support and encourage teachers to incorporate engineering in their NGSS instruction by providing access to necessary supplies. Engineering is a central part of the NGSS at all grade levels.

Provide teachers with professional learning on how to incorporate student agency and equity in their NGSS teaching. Some professional learning in the field tends to focus mostly on the "core" of the NGSS (i.e., 3D learning and phenomena). However, teachers also need practice, as well as guidance, in how to create spaces for student inquiry to drive instruction and how to utilize students' lived experiences to create deeper and more meaningful learning opportunities.

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Appendix A. Evaluation Methods

This report draws upon a variety of data sources. Evaluators directly observed 53 case study teacher lessons over the duration of the Initiative. They also carried out several surveys and many interviews with teacher leaders in the Initiative as well as interviewed Project Directors about impacts and challenges of NGSS teaching in their districts. Survey response rates are shown in Table A1.

Evaluators analyzed several case study teacher interviews, concentrating on their first and final interviews because those represented teachers' implementation of the NGSS at the beginning and end of their involvement in the Initiative. Because case study teachers' involvement in the Initiative had varying durations, the dates of the first and final interviews spanned several time points. Of the initial case study teacher interviews, 4 of 11 occurred in fall 2017, 3 of 11 occurred in fall 2018, 2 of 11 occurred in fall 2016, and 1 each was held in spring 2016 and spring 2017. All but 2 final interviews were held in spring 2020, with the remaining 2 occurring in spring 2019.

Evaluators also reviewed 8 additional interviews conducted between spring 2018 through spring 2019. These interviews were reviewed because teacher leaders shared specific examples of how they have used different strategies to implement the NGSS. Specifically, evaluators analyzed 3 interviews from spring 2018, 2 interviews from fall 2018, and 3 interviews from spring 2019.

In addition to the case study teacher interviews, evaluators examined 17 Project Director interviews from winter 2019–20 and spring 2020. In total, 9 Project Directors were interviewed at each time point, but 2 of these Project Directors were interviewed together in winter 2019–20.

Table A1. Survey response rates for Teacher Leaders and Core Teacher Leaders

Survey	2014–15		2015–16		2016–17		2017–18		2018–19		2019–20	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Early Implementers Spring Survey									309	63%	252	51%
Classroom Science Teaching Survey			352	76%	431	95%	361	73%				
Teacher Leadership Survey	452	73%	414	89%	443	98%	380	77%				

Note: In 2018–19 and 2019–20, we combined the Classroom Science Teaching Survey and the Teacher Leadership Survey into one survey, administered during the spring of each school year.

Glossary

5E instructional model — Based on how people learn (National Research Council, 2000), which says that learners build new ideas on top of old ideas, the 5E instructional model is driven by student questioning and discussion. The five stages of a lesson are engage, explore, explain, elaborate/extend, evaluate. Originally developed by Biological Sciences Curriculum Study (Bybee et al, 2006).

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

CA NGSS K–8 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.

Case study teachers — A small number of teacher leaders who provided the evaluation, with a look at NGSS implementation at the teacher and classroom level in Years 3–6 of the Initiative. Case study teachers were nominated by district Project Directors as those who were making some of the most substantial changes in their NGSS teaching. Each was interviewed twice per year; they were observed teaching an NGSS lesson for one or two class periods per year; and their students completed student surveys twice per year. The example lessons in this report are of case study teachers.

Claim, Evidence, Reasoning (CER) — Based on the NGSS science and engineering practices, primarily engaging in argument from evidence, and has been emphasized as a teaching strategy in Early Implementer training. The three ingredients together help students meet the overarching goals of the NGSS that they develop in-depth understanding of content and develop key skills related to critical thinking and communication.

Core Leadership Team (CLT) — Group of three to five administrators and five to eight teachers established at each district at the beginning of the Initiative. The CLT meets with its 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 districts or at projectwide events such as the Summer Institute.

Crosscutting Concepts (CCCs) — One of the three NGSS dimensions and a lens for understanding a phenomenon or problem. CCCs include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change.

Dimensions of the NGSS — The NGSS includes three dimensions: disciplinary core ideas (what scientists know), crosscutting concepts (how scientists make connections among the sciences), and science and engineering practices (what scientists and engineers do, and how scientific knowledge develops).

Disciplinary core ideas (DCIs) — One of the three NGSS dimensions. According to the 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 sciences.

Expansion teacher — Teacher who has not directly received significant professional learning or support from the Initiative but who is benefiting through the shared expertise of those who have. In larger districts, expansion teachers are typically in schools with at least one Teacher Leader.

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 anchor phenomenon.

K–12 Alliance — A WestEd professional learning program of science education leaders and professional learning providers who co-plan and co-deliver with Project Directors all projectwide activities for the Early Implementers Initiative.

Next Generation Science Standards (NGSS) — A set of K–12 science content standards developed by states to improve science education for all students. They are composed of Performance Expectations with accompanying three dimensions based on the National Research Council's Framework for K–12 Science Education. Adopted in California in 2013.

Phenomenon – Observable events that occur in the universe that cause us to wonder, and that we can use our science knowledge to explain or predict. There are two types of phenomena, anchor and investigative.

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 — Used by teachers to prompt students to discuss and make sense of scientific concepts and 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.

Science and engineering practices (SEPs) — One of the three NGSS dimensions, SEPs are the 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 to solve problems. 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; and obtaining, evaluating, and communicating information.

Summer Institute — During Years 1–4, a weeklong professional learning event held every summer to kick off the new Early Implementers school year. Attended by all Initiative participants, some as

leaders (Regional Directors, Project Directors, Core Leadership Team members) and others as learners (Teacher Leaders). In Years 5–6, districts held local Summer Institutes, open to all teachers of science in the district, that typically lasted for fewer than five days but consisted of similar activities and content. Teacher Leaders were Summer Institute leaders in the later years.

Teacher Leader — 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 of Years 1–4 of the Early Implementers Initiative. Each TLC 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 and debrief after each lesson is taught, during which they examine student work from the lesson and redesign the lesson to boost student sense-making. Each Teacher Leader participates in two TLCs per year. In Year 5, most districts continued to hold lesson studies as NGSS professional learning but tailored to district priorities.

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EVALUATION REPORT #13

Katy Nilsen, Ashley Iveland, Burr Tyler, Ted Britton, Kimberly Nguyen, Elizabeth Arnett