OCTOBER 2018 | EVALUATION REPORT #5

Making Middle School Science Whole

Transitioning to an Integrated Approach to Science Instruction

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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 evaluate the NGSS Early Implementers Initiative in the eight participating public school districts. This independent evaluation is advised by a technical working group that includes representatives of the California Department of Education and the State Board of Education. Evaluators investigate three main aspects of the Initiative's NGSS implementation:

- districts' local implementation,
- implementation support provided by K–12 Alliance, and
- the resulting science teaching and leadership growth of teachers and administrators, as well as student outcomes.

In addition to this current Report #5, evaluators previously released:

- *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)

Evaluators plan future reports on these topics:

- Teacher leadership
- Changed student interest in science

Executive Summary

The world around us is integrated. Fully understanding it therefore requires the application of multiple science disciplines. For years, middle school science courses in the United States have been configured to focus predominantly on one science discipline per grade (a discipline-specific model) — typically Earth science in grade 6, life science in grade 7, and physical science in grade 8. This discipline-specific approach exposes students to pieces of science in isolation and often leaves them unable to connect these fragments into a holistic understanding of science phenomena.

The Case for Integration

The Next Generation Science Standards (NGSS) advocate an integrated model of science instruction for middle schools in which the science disciplines are connected rather than separate. This model, used by other countries that are consistently successful in science, has several key benefits, including enhanced student learning and better preparation for the new California Science Test (CAST). The California Board of Education voted in 2013 to make integrated science the state's "preferred" model.

The K–8 NGSS Early Implementers Initiative was designed to support middle school science teachers and their administrators in integrating the sciences. From the start of the Initiative, all participating districts adopted the state's integrated science model. This fifth Early Implementer evaluation report examines how schools and districts in the Initiative are negotiating the transition to the integrated science model. The report draws on substantial data collected from teachers, administrators, and Initiative leaders through surveys, interviews, and classroom observations. This report also provides two detailed examples of integrated instruction through vignettes of classroom observations conducted in grades 6 and 8.

The Transition Takes Time and Planning

District progress varies. No district or school can switch entirely from a discipline-specific model to the integrated model in a single year. Most Early Implementer districts have detailed plans for making the switch to the integrated model, but their progress in executing them varies. After four years in the Initiative, some districts report being "very far along," with all teachers in the district on board and implementing mostly integrated instruction. Others, however, report less consistent progress, with teachers distributed across stages of integration, from coordinated but still discipline-specific science instruction, to a partially integrated approach, to the fully integrated model.

Professional learning is helping participants integrate the sciences. The Initiative is supporting districts in the transition in several key ways that have fostered understanding and planning at the district level and have helped teachers integrate science instruction in the classroom. For instance, hundreds of Teacher Leaders have experienced both planning and teaching integrated lessons through two of the Initiative's main professional learning components: Summer Institutes and district-based lesson studies during the school year.

Participants receiving extensive professional learning from the Initiative reported having a better understanding of integration than the "expansion" teachers and principals (i.e., those who have not participated in the Initiative's professional learning):

- 100 percent of surveyed administrators on the Core Leadership Team reported understanding "how to address more than one science discipline in a science unit"; a smaller proportion of the site principals *not* receiving training reported understanding integration.

- 89 percent of Teacher Leaders in grades 6–8 indicated understanding "fairly well" or "thoroughly" how to integrate multiple science disciplines in instruction; fewer expansion teachers indicated these levels of understanding.

Challenges to Integration

Not all lessons lend themselves equally well to authentic integration. A core strategy for helping Early Implementer teachers shift to NGSS involves focusing instruction on real-world phenomena that authentically draw on more than one science discipline. While evaluators and Initiative leaders and administrators have noticed a shift toward integrated teaching and learning based on real-world phenomena, Teachers Leaders report that not all individual lessons, or in some cases, units, fully lend themselves to authentic integration. In these instances, they recognize that integration between only two rather than all three science disciplines may be all that is possible.

Classroom configuration impacts science integration. While Teacher Leaders overall reported that they generally have been transitioning to integrated science instruction over the last two years, there has been notably less movement in grade 6. At this grade level, many teachers are in self-contained classes in which they teach all subjects, or block-type classrooms in which they teach one or more other subjects alongside science. In surveys, classroom configuration was found to strongly correlate with teacher understanding of how to integrate multiple science disciplines in instruction. For instance, a majority of expansion teachers teaching multiple science-only classes felt they understood integrated science instruction "fairly well" or "thoroughly." In contrast, a majority of those in the other types of classroom configurations (i.e., block and self-contained) felt that they understood "poorly."

Overcoming Obstacles to Achieving Full Integration

While Early Implementer districts have made progress toward implementing the preferred integrated model, some challenges have impeded complete success. For instance, substantial collaborative planning, especially between the middle grades, is crucial to ensure vertical alignment with what is taught at each grade so that students move on to high school without gaps in coursework. Teachers also face significant challenges, including having to teach new or less familiar science content, and having to let go of content and lessons that they have emotional connections to after having taught them for years.

Recommendations for Administrator Support of Integration

The report concludes with recommendations for administrators to help support the transition to integrated science instruction, including:

- Gain a basic understanding of integration
- Advocate for science integration
- Develop a multi-year transition plan
- Provide professional development
- Do not count on seeing integrated instruction in a single class observation
- Provide time, circumstances, and the expectation for substantial collaboration
- Provide time both to create model instructional units and to become familiar with, evaluate, and adapt any new materials
- Facilitate the shifting of supplies, facilities, and equipment, if needed
- Shift all classes to science-only courses with science teachers

Introduction

The Goal and Challenges of Integrated Science

The world is integrated. Therefore, fully understanding the world around us requires the application of multiple science disciplines.[1] For this reason, science educators for decades have advocated teaching integrated science, which involves drawing upon different sciences and engineering to understand whatever one is examining.[2]

There is a prevalent problem when it comes to teaching integrated science in the middle grades in California and elsewhere across the country: Science courses in the United States have been configured as predominantly one science discipline per grade (a discipline-specific model) — typically Earth science in grade 6, life science in grade 7, and physical science in grade 8. This discipline-specific approach often leaves students in an unsatisfying position of being exposed to pieces of science in isolation and unable to connect them into a holistic understanding of science phenomena. Also, because all science disciplines are taught in elementary school each year, students arriving at middle school could be puzzled at having to focus learning on mostly one science in a given year or course.

> "Students don't see science as being isolated in three separate science disciplines: life, physical, and Earth. They see it all related to each other.... If students come out at the end of the year with that understanding, that it's all connected, then we're doing what integration is about." (District Project Director)

The solution seems straightforward: switch to teaching all three disciplines each year and integrating the disciplines throughout the year. In fact, the California Board of Education voted in 2013 to make integrated science the "preferred" model, while still allowing districts to elect to continue an adapted version of the discipline-specific model described above.[3] It is important to note, however, that, due to the pedagogical shifts inherent in the new standards, the discipline-specific model is not the same as the middle school science model that was in widespread use before the NGSS.

From the outset of the California K–8 NGSS Early Implementers Initiative, all participating districts adopted the state's integrated science model. However, there are understandable reasons for other districts choosing to stick with the status quo (i.e., the discipline-specific model), including

1 Because engineering and its integration with the sciences has not been as strong an emphasis in the Initiative to date as attention to the sciences, this report most often uses language that only refers to science integration. However, the report's two classroom instruction vignettes illustrating integration both address engineering and the sciences.

2 For example, there was a previous major push for integrated science in California during the early 1990s, as described in *Building on Strength: Changing Science Teaching in California Public Schools* (Atkins, Helms, Rosiek, & Siner, 1997).

3 This report generally focuses on explaining the features and benefits of the integrated model rather than providing an analysis and comparison between the discipline-specific and integrated models.

several formidable challenges for teachers and administrators in changing to integrated science, such as:

- It can be easier for a teacher to focus on and be comfortable with teaching one science discipline instead of three.
- The structural changes required to rearrange science disciplines from separate grades into every grade require several years of schoolwide and/or districtwide transition.
- Teachers need substantial time to collaborate on crafting and implementing the transition plan, and for creating instructional units that integrate the sciences.[4]

The NGSS Early Implementers Initiative is supporting middle school science teachers and their administrators to address these challenges.

Benefits of Integrated Science

Enhanced Student Learning

Teachers are often excited to discover that learning science through integrated approaches better engages all students and promotes deeper understanding of the world around them, as noted by a district Project Director in the Initiative:

> ***Students don't see science as being isolated in three separate science disciplines: life, physical, and Earth. They see it all related to each other. . . . If students come out at the end of the year with that understanding — that it's all connected — then we're doing what integration is about.***

Because students are involved with each science discipline every year in the integrated model, it is a "spiral" curriculum (Bruner, 1960) where students revisit skills and build on concepts they learned in an earlier grade at a more complex level in a subsequent grade.

The California integrated model also reflects research from other countries that are consistently successful in science. These countries follow an integrated model of science instruction in middle school. This approach also prepares students for successful college science learning, and science careers.[5]

Better Preparation for the New California Science Test (CAST)

There are arguments for how the integrated model better prepares students for the new California Science Test (CAST), which soon will be on the California Dashboard. First, in the middle grades, CAST is administered at the end of grade 8. The test is cumulative, covering content from all middle grades — life, physical, and Earth and space sciences.

Second, the discipline-specific model creates distance between when concepts are studied and

4 Teachers have been needing to develop new instructional units that integrate the sciences in part because instructional materials having an integrated approach have not been adopted in California. However, of the potential science instructional materials recently examined by California's review panel, 16 of 29 were identified by the publishers as having some alignment with the preferred integrated model (CDE, 2018).

5 While science and engineering at the university level may appear mostly discipline-specific, students who major in these fields must take coursework in many different areas and draw on interdisciplinary knowledge regularly in order to be successful. Professional scientists and engineers also need knowledge and skills from multiple fields to answer questions or solve problems (NASEM, 2017).

when they are assessed in the CAST. An eighth-grader in a school following the discipline-specific model will not have been exposed to much Earth and space science for two years prior to the test, or life science for one year prior to the test, as those studies take place in grades 6 and 7, respectively. In contrast, an eighth-grader in a school implementing the integrated model will be learning all sciences every year, including the testing year.

Because the assessment is based on the Next Generation Science Standards (NGSS), some CAST questions require students to use science knowledge from two or more disciplines. Students having experienced only the discipline-specific model most likely will have had little opportunity to do this and may be at a disadvantage when compared to their peers learning through the integrated model.[6]

Evaluation Methods

In this fifth report in a series of Early Implementers Initiative evaluation publications, we examine how schools and districts in the Initiative are transitioning to the integrated science model.[7] Specifically, the report addresses the following questions:

- What are the national (NGSS) and state calls for integrating sciences?
- What does integration look like in the science classroom?
- What is the Initiative doing to support teachers to move to integrated sciences instruction?
- What is the status of implementation by districts, administrators, and teachers?
- What are the challenges for implementation?

Like the entire evaluation series for the NGSS Early Implementers Initiative, this report aims to be useful to school and district administrators, leaders of science professional learning, and state policymakers. Evaluators previously described the critical importance of administrators to all aspects of implementing the NGSS in *Administrators Matter in NGSS Implementation: How School and District Leaders are Making Science Happen* (Iveland, Tyler, Britton, Nguyen, & Schneider, 2017).

The evaluation draws from a substantial amount of data, from varied sources. The primary data sources are:[8]

- Annual surveys of teachers and administrators in Early Implementer districts who have received extensive professional development and support from the Initiative:
    - Classroom Science Teaching Survey (N = 111 science teachers)
    - Teacher Leadership Survey (N = 118 Teacher Leaders)
    - Administrator Leadership Survey (N = 17 Core Administrators)
- Annual surveys of teachers and administrators in Early Implementer districts who have not directly received significant professional learning or support from the Initiative but who are benefiting through the shared expertise of

6 These arguments for how the integrated model better prepares students for the CAST cannot be formally evaluated, however, until the new CAST is into its main administration phase (i.e., beyond field testing), and the state also acquires information about whether each district is implementing the integrated model or retaining the discipline-specific model.

7 This report does not discuss the integration of science with other school subjects. However, Evaluation Report #2, *The Synergy of Science and English Language Arts* (Tyler, Britton, Iveland, Nguyen, Hipps, & Schneider, 2017) extensively described the means and mutual benefits of cross-subject integration that were observed by the evaluators.

8 Specific survey questions and interview questions that Early Implementer participants were asked can be found in Appendix A and Appendix B, respectively.

those who have (we refer to these participants as "expansion" participants):

- Survey of expansion teachers (N = 81)
- Survey of expansion principals (N = 18)

- Interviews with select teachers and administrators in Early Implementer districts:
  - 23 case study teachers
  - 20 expansion teachers
  - 8 district Project Directors
  - 5 Regional Directors from WestEd who each serve 1–2 districts
- Observations of select teacher classrooms, including some case study teachers

Note that district Project Directors in the Initiative nominated case study teachers from among those who received extensive support from the Initiative, and who are making some of the most substantial changes in their teaching in relation to the NGSS. Additionally, Project Directors nominated middle school expansion teachers for interviews based on whether they were known to be integrating science disciplines in their instruction.

Additional evaluation data sources for the report are:

- Early Implementer district plans for NGSS integration
- Observations of key Initiative-wide or districtwide professional learning sessions

Calls for Integrating Sciences and Transitioning to New Approach

The NGSS call for integrating the sciences. Further, both these standards and the Science Framework for California Public Schools (referred to as the California Framework throughout the rest of the report) are organized in a way that empowers an integrated approach to teaching science. This section describes the integrated science model called for by the NGSS and the California Framework. Because moving to the integrated model requires substantial changes that take multiple years, the report also describes how the Initiative's participating districts, schools, and teachers are progressing toward implementing a fully integrated approach.

The Next Generation Science Standards

The NGSS advocate an integrated model of science instruction in which different science disciplines are connected rather than separate, as reflected in some key NGSS features:

- The NGSS call for routinely basing science instruction on authentic, local phenomena best explained by examining all of the relevant science disciplines (National Research Council, 2012).
- One of the three NGSS dimensions is "cross-cutting concepts," which are concepts that link across disciplines and are a vehicle for integrating disciplines.
- The standards themselves point out where integration between disciplines can happen through the "connections to other disciplinary core ideas (DCIs) in this grade-band." For example, a middle school standard in the life science grouping also cross-references the reader to connected DCIs in physical science and Earth and space science.

Progression Toward Full Integration While Transitioning

A previous NGSS Early Implementers Initiative evaluation report discussed why districts and schools pursing the integrated model must transition towards it over several years, and described such transition plans.[9] Certainly, no district or school can switch entirely from a discipline-specific model to the integrated model in a single year. One teacher gave evaluators this illustration of the problem:

9 See Report #1, *The Needle is Moving in California K–8 Science:* https://www.wested.org/resources/needle-is-moving-in-california-k-8-science-integration/

Table 1. Description of full, partial, and coordinated integration

Level of integration	Description
Full	Most science units during the year involve multiple sciences and can also involve engineering.
Partial	Science units often involve just two disciplines (and/or engineering) instead of all three (see Boyd et al., 2017). All three may or may not be covered throughout the year.
Coordinated	The school year is divided into portions in which one discipline is primarily taught — for instance, Earth and space science at the beginning of the year, life science in the middle, and physical science at the end.

In moving towards full NGSS and teaching the standards, we've had to really juggle some of the topics. For example. . .with the old standards matter and chemistry were definitely taught in eighth grade. But this year I had to teach it to seventh and eighth grade, because if I didn't teach it to eighth grade, in the way we worked out our transition sequence, then the eighth graders would have never had any chemistry or study of matter in middle school at all. They would have missed out on it this year. So we had to juggle some topics — genetics and chemistry/matter — to kind of make sure that the kids got it sometime before they went on to high school. (Grade 8 teacher)

In this report's findings, evaluators use a few characterizations of the status of participants' progression toward the intended full integration, as described in Table 1. In all cases of integration, instruction attends to multiple science disciplines in some fashion every year.

In any partially or fully integrated course, the goal is to engage students in science learning where they connect what they are learning across all relevant science disciplines to make sense of a scientific phenomenon. In coordinated integration, little attention is paid by the instructor to connecting disciplines; even though instructors may "refer back" to prior content, the science disciplines still are consistently siloed (see Sherriff, 2015). Nonetheless, coordinated integration is a valuable first step in the progression toward more ambitious integration. For example, the transition plan in Table 2, which shows how one Initiative district is progressing toward full integration, began with implementing a coordinated approach in the earlier years.

Table 2. One district's plan to transition from discipline-specific to integrated science model

Timing and degree of transition of topics	Grade 6 topics	Grade 7 topics	Grade 8 topics
2015–2016 (1998 standards)	Physics — Heat Energy Weather & Climate Geology & Natural Resources Ecosystems	Cells Genetics Evolution Earth History Organisms Body Systems	Chemistry Forces & Motion Astronomy
2016–2017 Coordinated 1 NGSS topic	**Physics — Heat Energy (NGSS)** Weather and Climate Geology & Natural Resources Ecosystems	**Cells & Organisms (NGSS)** Genetics Evolution Earth History	**Chemistry (NGSS)** Forces & Motion Astronomy
2017–2018 Coordinated 2 NGSS topics	**Cells & Organisms (NGSS)** **Physics — Heat Energy (NGSS)** Weather & Climate	**Cells & Organisms (NGSS)** **Chemistry (NGSS)** Ecosystems	**Chemistry (NGSS)** **Forces & Motion (NGSS)** Waves Astronomy
2018–2019 Full integration and NGSS	**All NGSS & Integrated** Physics — Heat Energy Weather & Climate Cells & Organisms Growth & Development	**All NGSS & Integrated** Chemistry Ecosystems Natural Resources & Geology (ex. Plate tectonics)	**All NGSS & Integrated** Evolution Forces & Motion Waves Astronomy

Source: Early Implementer district plan developed during the first 12–18 months of the Initiative.

Evaluation Findings

This evaluation report's findings address the following questions:

- What does integration look like in the science classroom?
- What is the Initiative doing to support teachers to move to integrated sciences instruction?
- What is the status of implementation by districts, administrators, and teachers?
- What are the challenges for implementation?

What Integration Looks Like in the Classroom

The following two vignettes, drawn from evaluators' observation of a grade 6 teacher and a grade 8 science teacher, introduce what integration can look like in the classroom. A future evaluation report on the topic of integrated science teaching slated for fall 2019 will include more classroom vignettes.

Observed Grade 6 Lesson: Surviving on Mars

A grade 6 teacher who teaches all subjects at her elementary school entered the Initiative with minimal science background. She has been using and revising this lesson in her classroom since she saw it during the Initiative's first Summer Institute. She is pleased with the result, a lesson sequence that authentically incorporates not only the physical, Earth and space, and life sciences, but also engineering design. She gives an overview of the "story line" of the full lesson sequence:

> ***It's kind of a combination of physical and Earth science, because the storyline is how ocean currents move and how these patterns are created through thermal energy transfer and also the water cycle. And then their little habitat should include those two things, and life science too for survival on Mars. This engineering challenge is them taking their science knowledge and applying it to a new scenario.***

On the board the teacher has written, "Write down everything you know about what living things need to survive. Use all the science knowledge you learned this year to do this." Students take a few minutes to write their ideas in their science notebooks. As students share out their ideas about what is absolutely necessary for survival, the teacher engages with them to elicit deeper thinking about some items through questioning strategies rather than correcting them or offering her own knowledge. Eventually the class settles on the following list of what humans need to survive on Earth: water, food, oxygen, and "shelter, especially if you're in an area that is either hot or cold."

The teacher then shows a slide introducing students to the topic they will be engaged in for the next three weeks. It is an engineering design challenge: to address the problem of overcrowding on Earth, NASA needs engineers to design a habitat that can support humans on Mars (see Figure 1). Students will be designing, building, and testing model habitats for Mars.

Figure 1. Introducing the design challenge

Source: Teacher's slide shown during a lesson observed by the evaluation team in spring 2018 (Larwin & Orwig, 2016).

Students first are prompted to consider and record in their notebooks what they need to know or think about when designing their Mars habitat. Students come up with a number of factors to consider, for example: "Temperature. How hot or cold it gets there." "How far from the sun, in miles?" "Obviously, Mars doesn't have water and stuff, so where are we going to get water from?" "Does Mars have any sort of wind or weather?"

Students discuss in their small groups the items that represent the absolute bare minimum that humans need to survive. After a lengthy debate and a process of elimination of less critical factors, the class decides that if a habitat maintains a steady temperature and harnesses the water cycle, then it will be successful on Mars (their "criteria for success").

The teacher tells the group that their habitats will be enclosed in sealable, clear containers, such as an empty soda bottle. She reminds them that they are limited by other constraints, including budget. With that in mind, the teacher asks students to come up with some ideas for materials they may need to build their habitat models. She writes down all of the "doable" materials they ask for, with the intention of getting them in time to start building and testing. Many of the items she already has on hand, such as:

- Black garbage bag
- White paper
- Black paper
- Bark
- Rocks
- Aluminum foil
- Potting soil

The rest of the day's lesson is guided by two questions:

- Which materials work best for sustaining a constant temperature?

- Which materials could be used to create the water cycle inside your jar or bottle?

Working in small groups, the students select one of the materials, record the initial temperature of material and then take it outside. They record the temperature of their material after 20 minutes in the sun. Before the lesson ends, students return to the classroom and share their findings with the rest of the class. Later, students will design, build, test and retest their habitat models, working through the engineering design process. As part of their designs, they will predict how the materials they chose will enable the habitat to sustain a stable temperature and harness the water cycle.

Though much of the science in this lesson sequence on building protective shelters for human survival on Mars addresses physical science (e.g., heat transfer) and Earth and space science (e.g., the water cycle, weather and temperature, conditions on Mars), students were also addressing some relevant life science concepts (e.g., conditions needed for survival). Students were also engaging in a full three-dimensional experience by covering many of the science and engineering practices (e.g., asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, designing solutions) and crosscutting concepts (e.g., energy and matter, systems and system models, patterns, stability and change). This lesson sequence highlights how teachers who have limited experience or background in science or engineering can become effective science and engineering teachers, fully capable of adapting and teaching integrated science lessons.

Observed Grade 8 Lesson: Causes of Mass Extinction Events

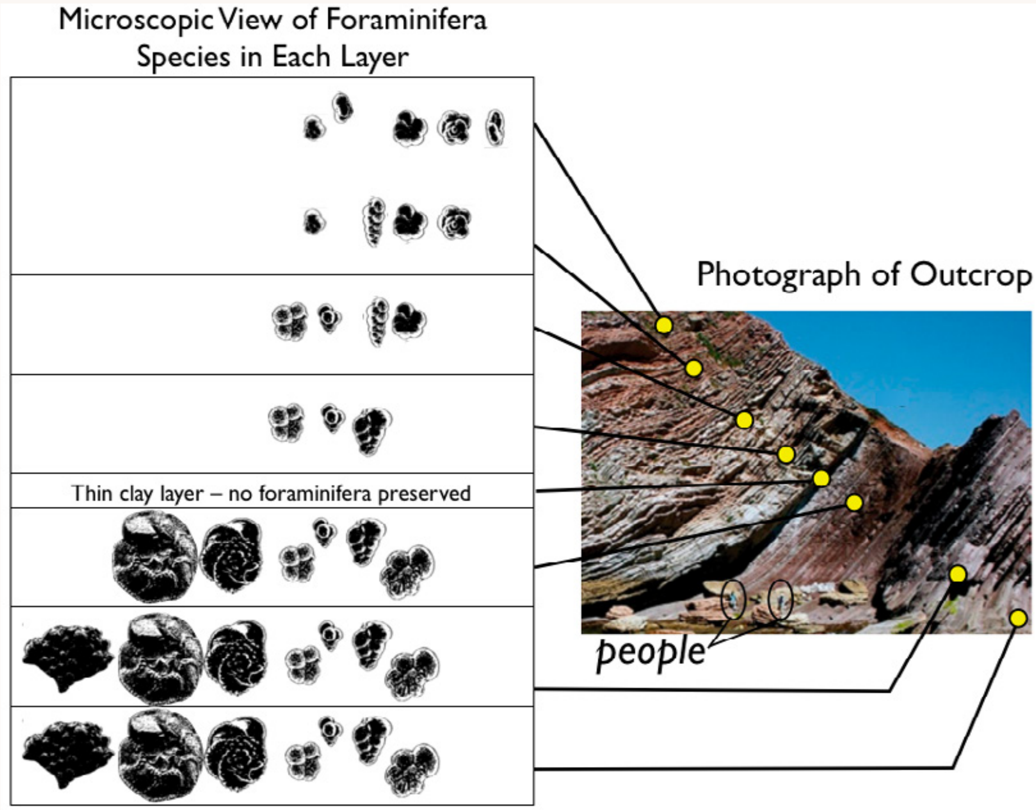
This observed lesson was taught by an expansion teacher whose grade 8 Teacher Leader partner has consistently shared learnings and lesson sequences from her experiences with the Initiative. Their principal has afforded the pair time and flexibility to collaborate, and, consequently, both are engaged in NGSS-aligned, integrated science instruction.

This lesson sequence focuses on possible causes for a mass extinction event. Before the observed lesson, the teacher prompted students to recall what they had done and learned previously about rocks and stratification. Recalling this information would help the students make sense of the anchoring phenomenon for the current unit,[10] a rock formation found in Northern California. This, however, is not the only previously learned knowledge that students would bring to bear during the day's lesson.

The teacher presents the class with a picture of rock strata and the fossils found on either side of a striking, dark "boundary line" clearly present in the rock formation (as shown in Figure 2). This graphic shows that below the line are more diverse and larger fossils, while above the line there are only smaller fossils. The class surmises that something must have happened to make many of the larger living organisms die off, and they wonder what it was.

10 An in-depth description of using phenomena as a tool for integration is provided in this report's section entitled "Basing Integrated Instruction on Real-World Phenomena."

Figure 2. Anchor phenomenon: Fossils found on either side of a rock formation "boundary line"



Source: Teacher's graphic shown during a lesson observed by the evaluation team in spring 2018.

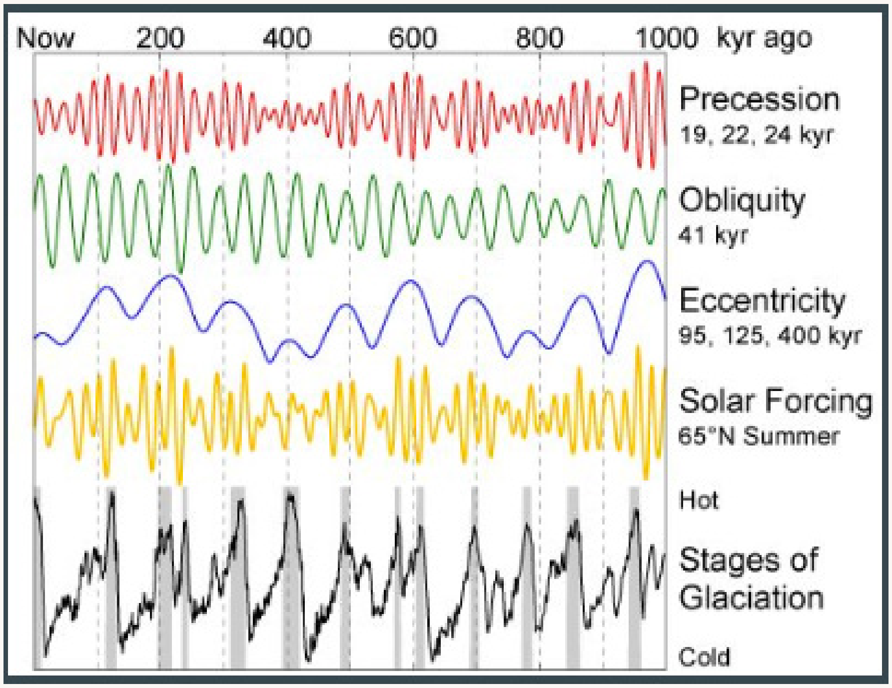
The teacher states that the scientific community has come up with three claims to explain what caused the extinction event:

1. The influence of **the variation of the Earth's orbit** on climate.
2. The influence of **an asteroid impact** on climate.
3. The influence of **a super-volcano eruption** on climate.

However, the experts cannot agree which of the three claims is correct. The teacher tells the students that, during this unit of instruction, students will examine each claim to determine the one they think accurately explains the cause of the extinction event. A quick poll to see which of the three claims students think is the most likely cause of the extinction event reveals that most believe a change in Earth's orbit would have a larger, more global effect than the other two. So, the class starts their investigation there.

The teacher asks the group how they would go about investigating claim #1. Students say they would look at how much variation there has been in the Earth's orbit. They remember seeing a chart of orbital effects on climate over time earlier this year, and they have information about it in their notebooks. The teacher displays the chart (shown in Figure 3) for them again. She instructs them to use the data in the chart and their notes to develop a predictive model showing how much

Figure 3. Graphic showing trends over time in variables of the Earth's orbit



Source: Teacher's graphic shown during a lesson observed by the evaluation team in spring 2018.

variation there could have been in the Earth's orbit around the sun 1.5 million years ago.

Students begin work on their individual models of the Earth/Sun system. The teacher suggests that they first assume "a perfectly circular orbit and a steady sun." Next, they should manipulate the variables of axial tilt (obliquity), rotation or wobble of the axis (precession), and the shape of Earth's orbit (eccentricity).

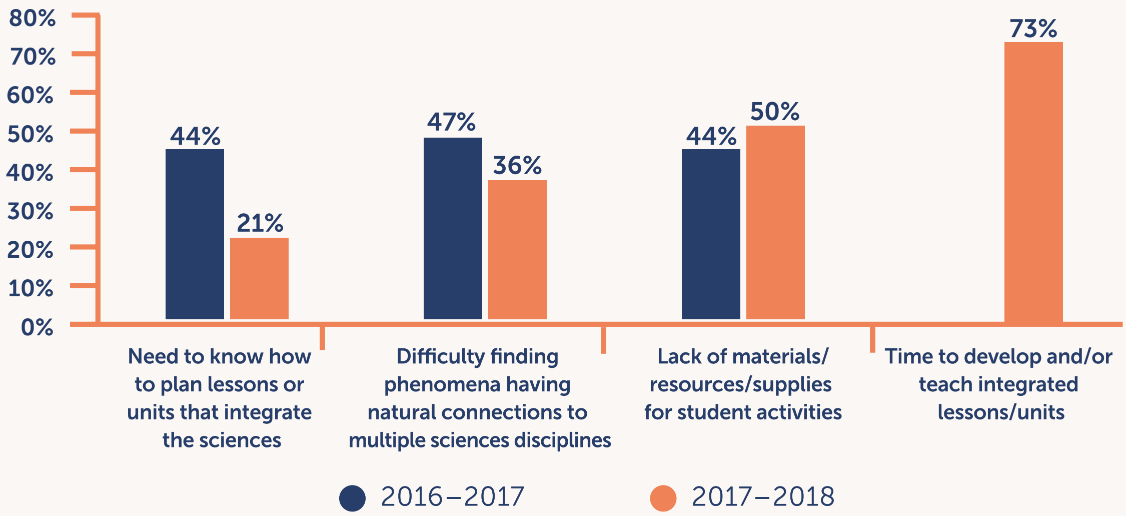
The teacher then encourages them to use their understanding of physical science and Earth and space science to think about the way the sun's rays hit the Earth and how that would, in turn, affect the surface temperature on the Earth; the variability of temperature from place to place on the planet; and the long-term climate under those conditions. Throughout this activity, students discuss in their groups, read and write in their science notebooks, and confer with the teacher.

Every five or ten minutes, the teacher brings the class together to discuss key ideas or questions, or to clarify instructions. By the end of the lesson, they decide as a group that changes in the Earth's orbit likely did not have sufficient impact on the climate to achieve a mass extinction event, but they still want additional evidence to be certain.

Later in the unit, students will collect additional evidence relating to the other claims and will use their evidence to determine which claim accurately explains the cause of the mass extinction event observed in the geology of Northern California. To do this, the class will also study how living things adapt and survive through various mechanisms (including natural selection). Last, the unit will move into the effects of humans on the Earth and on other living things on the planet. Students will be asked, based on what they have learned about extinction in the past, whether they believe there could be another extinction

Figure 4. Comparison of what Teacher Leaders identified as some of their biggest instructional challenges for transitioning to the integrated model for science, 2016–17 and 2017–18

Please identify up to three of your biggest challenges for transitioning to the California preferred integrated model for science



Source: Classroom Science Teaching Survey administered by WestEd, analyzed only for teachers of grades 6, 7, and 8 in 2016–17 (N=156) and in 2017–18 (N=111).
Note: "Time to develop and/or teach integrated lessons/units" was not a response option in 2016–17.

event from climate change due to human activity on Earth. While the observed lesson within this unit emphasizes one science discipline, Earth and space science, the overall unit clearly includes and integrates all three.

How the Initiative Is Supporting Integrated Science Instruction

In an evaluation survey, Teacher Leaders were asked to identify from a list of eight possibilities their biggest challenges for transitioning to the California integrated model for science. Among the top challenges they identified were "need to know how to plan lessons or units that integrate the sciences," "time to develop and/or teach integrated lessons/units," "lack of materials/resources/supplies for student activities," and "difficulty finding phenomena having natural connections to multiple science disciplines" (see Figure 4).

The Initiative has been addressing these concerns. The data in Figure 4 show significant progress has been made on two of these challenges. This progress is likely due in part to the Initiative's focus on phenomena and its provision of opportunities for teachers to learn, experience, and plan for integration. The challenge of lacking time to develop and/or teach integrated lessons may be lessened in future survey data because: teachers are continuously creating more lessons and sharing them with each other; the Initiative is producing exemplar learning sequences that many teachers are beginning to use; and some commercial science instructional materials in the current 2018–19 state adoption may adequately address central NGSS instructional emphases, including integration. Obtaining supplies for hands-on student investigation is frequently a challenge for teachers, but participating districts as well as some school sites are increasingly aiding teachers in obtaining materials.

Initiative Opportunities to Learn, Experience, and Plan for Integration

The hundreds of Teacher Leaders in the Initiative have had opportunities to gain experience with integrated instruction in two of the Initiative's main professional learning components: Content Cadre time during the annual Summer Institutes, and lesson study sessions (Teaching Learning Collaboratives) back in their districts during the year. Expansion teachers in Initiative districts have not had these opportunities, but since the 2016–17 school year, districts have begun rolling out NGSS professional learning opportunities for all teachers, which include some attention to science integration.

Content Cadres within Summer Institutes. The Content Cadres comprise approximately 50 percent of the annual week-long Summer Institutes for Teacher Leaders that kicked off each year of the Early Implementers Initiative during its first four years. Led by teams of experts, including a university or business scientist and two expert teachers, Content Cadre sessions:

- Provide hands-on learning activities that model NGSS instruction in the classroom in which Teacher Leaders take on the role of the student; and
- Increase teachers' understanding of grade-level content specified in the NGSS and of pedagogical approaches to teaching science, including how to integrate science disciplines.

For middle school Cadres, one of the leaders typically is a middle school teacher. To ensure a focus on integrated science, particularly at the middle school level, each Content Cadre leader represents one of the three disciplines: life science, Earth and space science, and physical science.

In interviews, many Teacher Leaders said that the Cadre experience helped them understand how to teach integrated science, as illustrated by the following remarks:

> ***The lesson from Cadre really opened my mind to how things can be integrated, for example how you can do a mini lesson in a certain science discipline to teach a particular concept more deeply, then come back to the main theme that is from a different discipline. (Grade 8 teacher)***

Teaching Learning Collaboratives (TLCs). These Early Implementer lesson studies bring together same-grade teachers, typically from different schools in the district. The teachers spend a planning day fleshing out an individual lesson within a unit that they previously designed. On a second day, participants co-teach an NGSS-aligned lesson two times, debriefing and adjusting the lesson with an Initiative-trained facilitator after each teach session. This results in an integrated lesson that teachers can take back to their classrooms and use on their own or share with their colleagues. Exploring and practicing how to integrate the sciences is one of many facets of NGSS instruction that participants tackle during the TLCs.

When interviewed, one Project Director talked about how teachers in his district used the learning sequence that they created during a TLC: "During TLCs they are purposeful about developing lessons that are truly integrated. We hope that the Teacher Leaders are spreading what they develop in the TLC sessions with other teachers at their grade levels as well." A Regional Director noted that the TLCs have provided time for teachers to delve into planning in a truly integrated way, which she laments teachers often do not get to do:

> ***But if you have a whole day and you're designing a lesson within a learning sequence, then you can talk about integration really deeply. I have seen individual lessons that integrate disciplines more often in TLCs now.***

During some TLC planning days, teachers plan an instructional unit rather than just the one science lesson that is tried on the subsequent teach day. Facilitators help teachers use and create "conceptual flows" for the unit. A conceptual flow is both a process and a product. It is a process of collaboratively developing a storyline for a phenomena-based, integrated, NGSS-aligned unit of instruction by a team of teachers, typically from the same grade level. At the end of the process is a product — a conceptual flow graphic — where concepts are arranged into an instructional sequence for teachers to use to structure their lessons to facilitate students' learning over time (usually several weeks to a full academic year). The process of developing a conceptual flow around phenomena often leads teachers to see connections among the science disciplines and gives them an opportunity to incorporate these multiple disciplines and ideas into their instruction.

Basing Integrated Instruction on Real-World Phenomena

A core Initiative strategy for helping teachers shift to NGSS instruction — which participants learn in the various professional learning opportunities described above — is to design student-driven learning focused on understanding real-world "phenomena."[11, 12] Using phenomena as the basis for student inquiry and instruction also serves as a key strategy for integrating the sciences. Students quickly become engaged in a science lesson that begins with exposure to naturally occurring phenomena, for example: sick sea lions are appearing on the beach, the harvest of apples is going down in Julian, California, and some materials get hotter than others in the sun.

Such phenomena can get students wondering about what is going on and can get them more willing to learn science and do engineering to answer the questions that arise. Drawing on the authentic context of phenomena, teachers can integrate relevant science disciplines into the lessons, rather than artificially separating the teaching and learning of physical, Earth, and life science. A Regional Director emphasized that a "game changer" for teachers transitioning to integrated science is "realizing that anchoring your instruction to phenomena is really powerful for kids and recognizing that it's really hard to fully explain a phenomenon with just one discipline, with very rare exceptions."

One Project Director said that he has noticed a shift in the way teachers are planning lessons: "Teachers start off by thinking of phenomena and start thinking about the SEPs [science and engineering practices] students will engage in, instead

11 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."

12 A prior evaluation report, *Next Generation Science Standards in Practice: Tools and Processes Used by the California NGSS Early Implementers* (2018), provides expanded descriptions of phenomena and their instructional use, as well as other strategies and activities discussed in this section.

of just thinking about the DCIs [disciplinary core ideas]." In other words, phenomena and science and engineering practices are just as instrumental as the content, and work in tandem to provide students with authentic learning experiences. A Teacher Leader provided an example of how she used an anchoring phenomenon to integrate the physical and life sciences:

> *I think I've done a pretty good job this year of incorporating physical and life science Performance Expectations utilizing anchoring phenomena. I've used the arctic ice melting to talk about physical science things related to properties and states of matter. Then also bringing in human impact and population dynamics, because as the arctic ice is melting, that's affecting the ecosystem and the community of plants and animals that live in this environment. (Grade 8 teacher)*

Another Teacher Leader discussed dilemmas in selecting a phenomenon that would be applicable to multiple science disciplines:

> *So if you're learning about energy going through an ecosystem, for example . . . you've got the chemistry, and then there's life science, but then where is the Earth science? Do you do all three every lesson? Do you do one discipline one day or do you address them all differently and then at some point bring them all together in some sort of a project or something, where the students use the information that they've learned from the different disciplines and kind of put it all together to explain the phenomenon? I guess that's where I kind of get stuck sometimes, in trying to find a phenomenon that really hits a variety of disciplines that you can really go deep into and really learn some important things in each of those disciplines in order to explain that phenomenon. (Grade 7 teacher)*

Whether a phenomenon should integrate all the science disciplines or if it is acceptable for a phenomenon to only relate to two disciplines was a common topic of discussion among Early Implementers. Some teachers felt that certain science disciplines were easier for them to integrate than others, with many saying that they struggled to purposefully incorporate all three disciplines around many of the phenomena they selected. Many Teacher Leaders have assured their colleagues that it is okay sometimes to select a phenomenon that only hits two disciplines.

While the Initiative supports aiming to integrate all sciences as authentically as possible during an instructional unit, it can be common for only one science discipline to be emphasized in a single day's lesson within that unit, as explained by this district Project Director:

> *There will be times when one lesson definitely can pull in two or three disciplines. . . . I said to my teachers, "You know what? When it makes sense to do that, then do it. But if it's forcing the issue, then that's probably not the most effective thing to do with the kids." If you're having to force it, then it's not going to make sense to them. If it's not a place that's going to deepen their understanding, then it would not be good instruction just to be able to say, "We're integrated!"*

Teacher Leaders also described how a unit can be planned as integrated science and can be integrated throughout the school year, but individual lessons can often end up being taught in a "coordinated science" manner. In a survey response, one Teacher Leader wrote:

> ***The lesson sequence [unit] will be integrated. However, when a teacher teaches students for only 50 minutes, those small chunks of time will not necessarily be integrated. . . . Ultimately, on the summative assessment, the students can explain in an integrated manner, but day by day, an individual lesson usually ends up coordinated, or only a single discipline.*** *(Grade 8 teacher)*

The Status of Integration

Over multiple years of the Initiative, the evaluators have observed a mix of reactions to the idea of switching from a discipline-specific model to the integrated model — from enthusiasm, to angst, to resistance. In the early years of the Initiative, some participating teachers and administrators were slow to change to the integrated model. Some cited that this was partly because there was not yet an operational California Science Test (CAST) that favored integration for optimal student performance. While it may or may not be due to the approaching operational state science test, Early Implementer districts' efforts to integrate science instruction do seem to be spreading to include more participants.

Understanding Integration

Participants must first understand how to integrate science disciplines in classroom teaching and learning before they can do it. To get a better sense of how well administrators and teachers understand integration, evaluators carried out interviews and surveys with those involved in the Initiative. The following results from those interviews and surveys show the understandings of administrators and teachers. For each group, the professional learning and support provided by the Initiative had an impact. That is, the participants receiving extensive support from the Initiative reported having a better understanding of integration than the "expansion" teachers and principals who are not attending professional learning provided by the Initiative.

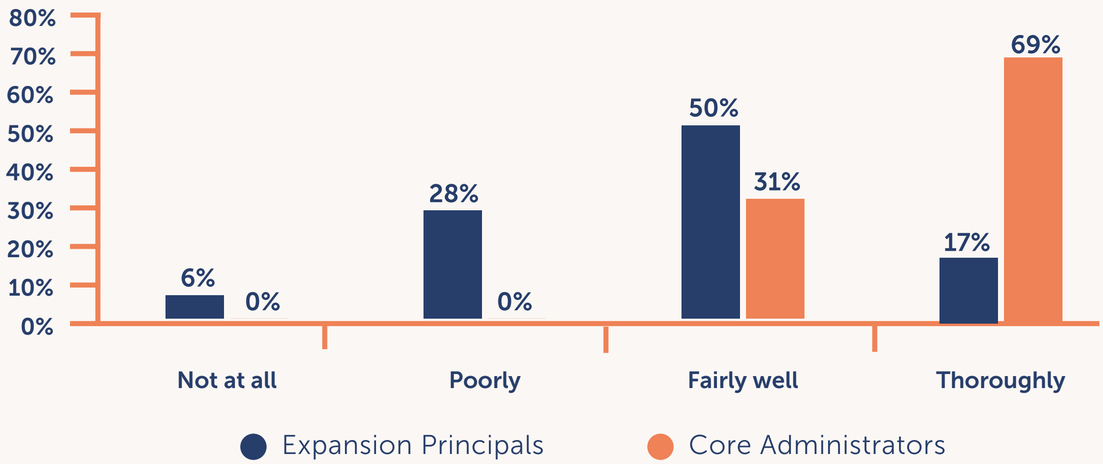
Administrator Understanding. One district Project Director emphasized how important it is that administrators understand and support how teachers will be teaching integrated science:

> ***A priority for the transition to the integrated model should be that administrators have enough training and awareness to realize what this entails, and what it could look like in a classroom, and to provide teachers with support [and] . . . encouragement to keep trying things.***

In fact, as of spring 2018, 100 percent of surveyed administrators on the Core Leadership Team (Core Administrators) reported that they understood "how to address more than one science discipline in a science unit," with 69 percent indicating that they understood "thoroughly" and 31 percent indicating they understood "fairly well" (see Figure 5).

Figure 5. Expansion principals' and Core Administrators' understanding of how to integrate multiple science disciplines

How well would you say you understand how to address more than one science discipline (i.e., Earth and space, life, physical) in a science unit?



Source: K–8 Survey for Principals, analyzed for only middle school and K–8 principals, administered by WestEd in 2017–18 (N=18) and Administrator Leadership Survey, analyzed for only those working with middle grades (6–8), administered by WestEd in 2017–18 (N=17).

Not surprisingly, fewer of the site principals who were *not* receiving training from the Initiative (expansion principals) reported understanding integration: about two-thirds described understanding integrating either "thoroughly" (17 percent) or "fairly well" (50 percent). On the other hand, about a third of expansion principals reported understanding "poorly" (28 percent) or "not at all" (6 percent).

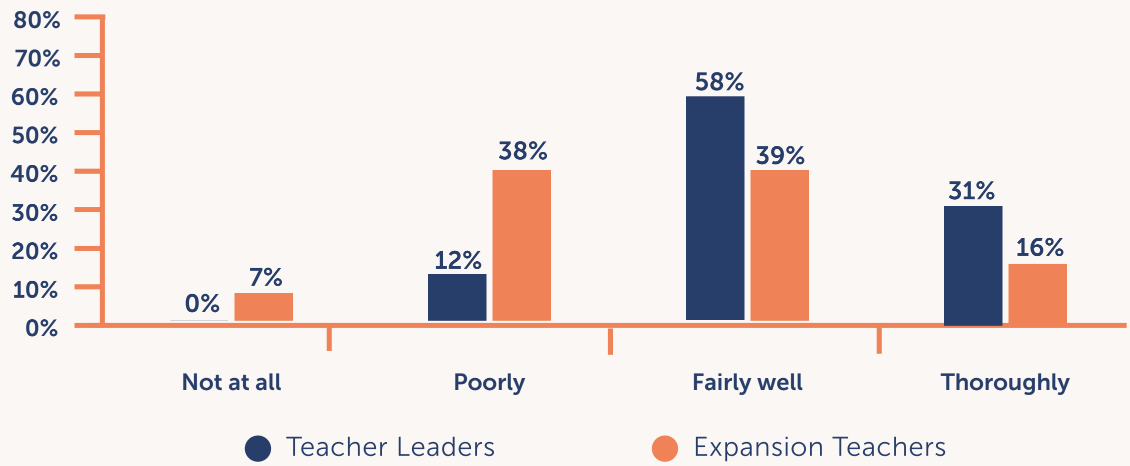
Teacher Understanding. The great majority of the Initiative's Teacher Leaders in grades 6 through 8 indicated understanding "fairly well" (58 percent) or "thoroughly" (31 percent) how to integrate multiple science disciplines in instruction. As expected, fewer expansion teachers indicated these levels of understanding (see Figure 6).

There were also differences based on the classroom configuration of surveyed teachers (see Figure 7). Many middle grade teachers, especially in grade 6, are not teaching multiple science-only classes. Rather, some teach "block courses" where both science and another subject are taught together as a block, with mathematics being most common.[13] Such block courses are often not staffed by trained science teachers. For example, it is common for a science-mathematics block course to be staffed with a mathematics teacher. Additionally, some middle grade science teachers are in self-contained classrooms teaching all subjects, including science. This configuration, along with block courses, is most common in grade 6 (grades 7–8 consist of multiple science-only classes, while science in grade 6 is taught by teachers who are responsible for other subjects as well). This configuration is common in both K–6 and K–8 schools, but can also occur in middle schools.

13 This "block course" configuration should not be confused with "block scheduling." A block schedule is when any subject is taught during a class period that is twice the length of a normal schedule (e.g., 90 minutes, rather than 45).

Figure 6. Grade 6–8 teachers' understanding of how to integrate multiple science disciplines

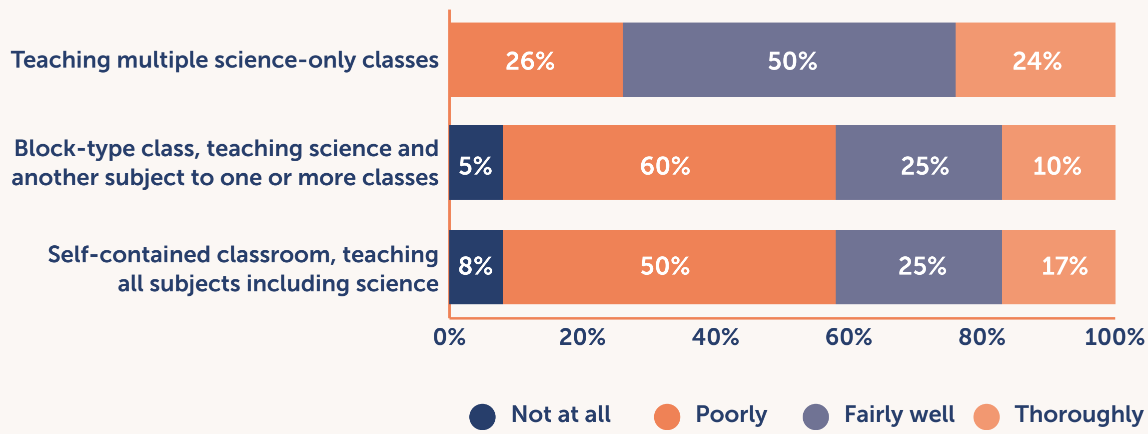
How well do you understand how to address more than one science discipline in a science unit?



Source: Responses of middle school teachers to the Teacher Leadership Survey (N=118) and Survey for K–8 Science Teachers (N=81) administered by WestEd in 2017–18.

Figure 7. Grade 6–8 expansion teachers' understanding of how to integrate multiple science disciplines, by classroom configuration

How well do you understand how to address more than one science discipline in a science unit?



Source: Responses of middle school teachers to the Survey for K–8 Science Teachers administered by WestEd in 2017–18 (N=81).

When expansion teachers' understanding of how to integrate science disciplines in their instruction were analyzed by these three main classroom configurations, differences in their understandings emerged (see Figure 7).

Among expansion teachers, a majority of those teaching multiple science-only classes felt they understood integrated science instruction "fairly well" or "thoroughly." In contrast, a majority of those in the other types of classroom configurations (block and self-contained) felt that they understood "poorly." A similar but less pronounced contrast appeared among Teacher Leaders in these same classroom configurations (not shown in Figure 7). Teacher Leaders who taught multiple science-only classes indicated a good understanding (with 67 percent understanding "fairly well" and 30 percent "thoroughly"). However, 15 percent of Teacher Leaders in block courses and 39 percent of those in self-contained classrooms reported "poor" understanding.

The above findings indicate that it is not only the amount of professional development that administrators and teachers receive that can affect their understanding of how to integrate science disciplines in instruction. The classroom structure within which teachers work can also have a profound effect on their preparedness.

District Transition Plans

While most Initiative districts have detailed plans for transitioning to the integrated model, their progress in executing them varies. In some districts where there is more teacher collaboration and coordination across the middle grades, teachers have been developing and implementing more integrated lessons in their classrooms. Two district Project Directors indicated that their districts were "very far along" and all teachers were on board with integration. These districts have been creating integrated units of instruction that they are encouraging all teachers in the district to use and modify as needed.

Even in districts where teachers reported solid progress, some teachers were slow to change. One district Project Director acknowledged, "Some expansion teachers are still teaching in silos thinking that might be integration. They're hitting all the different disciplines, but maybe not simultaneously." Three other district Project Directors shared similar stories, reporting that the transition from discipline-specific to coordinated was relatively easy because it just required some "shifting around of content" between grade levels, but the shift from coordinated to fully integrated has been slower than anticipated.

A Regional Director supporting one of these districts remarked, "The district didn't actually do 'integrated,' they did 'coordinated.' So, they were just putting things in as they fit for the new 'integrated model,' but not actually integrating the content meaningfully." In four districts that were at various stages in the process of transitioning, teachers noted seeing colleagues who were reluctant to shift to full integration because they were waiting for curriculum to be adopted. The Project Director of one of these districts noted that, despite having had a transition plan for a few years, "Transition won't happen until *after* materials are adopted."

Teacher Shifts to Integration

Surveys of Teacher Leaders over the last two years showed that they generally have been transitioning to integrated science instruction, as shown in Table 3. However, there are far more Teacher Leaders in grade 6 (versus grades 7 and 8) who still describe their instruction as discipline-specific. There was also a sizable increase in the number of those in grade 8 who now describe their instruction as integrated (up to 65 percent in 2017–18 from 58 percent in 2016–17).

When expansion teachers were asked how often they addressed more than one science discipline in a science unit, 67 percent of grade 8 teachers reported teaching integrated science at least monthly. In contrast, 55 percent of grade 6 expansion teachers reported teaching integrated science less than monthly, with almost one third (29 percent) reporting that they taught an integrated science unit only 1–3 times all year, and 14 percent saying they never taught an integrated unit. These findings again highlight that while there is more significant movement in

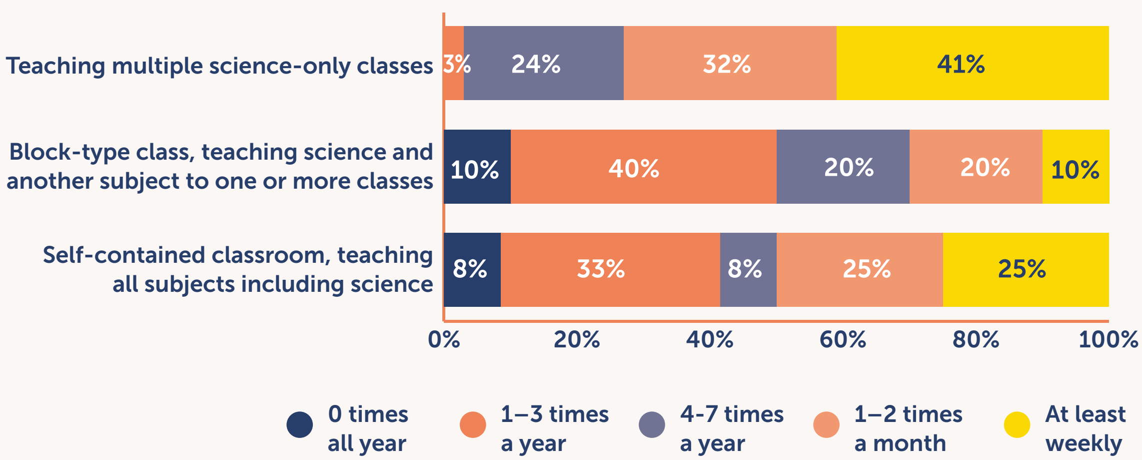
Table 3. Comparison of grade 6–8 Teacher Leaders' science instruction over two years, by grade level

Grade level	Discipline-specific 2016–17	Discipline-specific 2017–18	Coordinated 2016–17	Coordinated 2017–18	Integrated 2016–17	Integrated 2017–18
Grade 6	15%	11%	41%	39%	44%	50%
Grade 7	12%	7%	26%	32%	62%	61%
Grade 8	12%	3%	31%	32%	58%	65%
Total	**13%**	**8%**	**36%**	**34%**	**51%**	**57%**

Source: Responses of middle school teachers to the Classroom Science Teaching Survey administered by WestEd in 2016–17 (N=156) and 2017–18 (N=111).
Note: Teachers were asked to respond to the following question: "Which description below best describes your science instruction (including stand-alone science and science integrated with other subjects) during the 2017–2018 school year?"

Figure 8. How often grade 6–8 expansion teachers taught science units that addressed multiple science disciplines, by classroom configuration

How often did you address more than one science discipline in a science unit?



Source: Responses of middle school teachers to the Survey for K–8 Science Teachers administered by WestEd in 2017–18 (N=81). Values for some groups do not sum to 100 percent because responses for "0 times" are not included.

transitioning to integrated science instruction in grades 7 and 8, grade 6 is showing slower progress and may require additional supports.

Figure 8 shows how frequently expansion teachers reported teaching units that integrate multiple science disciplines, with teachers grouped by classroom configuration: block course, science-only course, and self-contained classroom. About three-fourths of teachers who taught multiple science-only classes reported teaching integrated science units at least once per month. The teachers who taught the least integrated science were those with a block course; half of these teachers taught integrated science units less than four times all year. Teachers in self-contained classrooms teaching all subjects also taught integrated science much less often than those teaching science-only classes. A minority of teachers of block courses (10 percent) and self-contained classes (8 percent) even reported that they never taught units that integrate the sciences. In contrast, none of the teachers of science-only courses similarly indicated a complete absence of integrated units (not shown in Figure 8).

Challenges

Need for Substantial Collaboration

With the new integrated science model, it is crucial that *all* middle grades have vertical alignment because the science content shifts among these grades are substantial. It is important that all teachers know which science concepts are to be taught at different grade levels under the NGSS compared to the previous science standards. Further, all teachers should have a voice in shaping the transition plans. Cross-grade conversations let teachers fully capitalize on vertical alignment, as described during a teacher interview:

> *We've been asking for time for vertical alignment to check on prior grades. It's really important for kids to be able to refer back to what they learned before and I want to check in with my students to figure out their prior knowledge. We're now seeing kids who have had one or two years of NGSS already, and we want to tap into that to say, "Okay, I know that you should have studied this and this in 6th and 7th grade. Let's make connections and go from there." (Grade 8 teacher)*

One strategy that many Early Implementers are using is to designate at least some on-site teacher collaboration time (e.g., regularly scheduled time for professional learning communities) to coordinate integrated science across grades 6 through 8. By creating this kind of designated time for teachers to work through the vertical alignment of science instruction, teachers can develop instructional sequences for each year, determine which grade level is teaching what content, and work to ensure that all students will receive everything they need throughout the middle grades.

Teacher Comfort with and Interests in Different Science Disciplines

Collaboration can also be used for developing all grade 6–8 teachers' science content knowledge and pedagogy around all science disciplines. Because many middle grade teachers come from specialized science backgrounds or have many years of teaching within a single science discipline, some have found it difficult to feel equally knowledgeable and comfortable with the other content they now must teach. One grade 6 Teacher Leader related:

> *I'm more comfortable teaching Earth science because I've been teaching that for 17 years. It's hard to integrate [something] like cells, because I didn't know that curriculum. I had to research it so I could understand it better. When I was doing research, I found great stuff. It's not that I couldn't do it, but it just took so much time, which is why it's good to be in a team.*

However, as this grade 8 teacher described, teachers can gain relevant science content knowledge in new areas through research or practice on their own, but they need time to do this:

> *I come from a science background. . . . I have a masters in ecology and evolution. So, the Earth science stuff is not my forte. Finding the time for me myself to fully research, and make sure that I fully understand everything is a big challenge.*

A district Project Director described that, for some teachers, the reluctance to teach new science content was less a matter of lack of time or knowledge and more of a matter of lack of emotional connection to the content they taught:

> *It's been a "my favorite area of science to teach" issue, thinking of yourself as a life science teacher. So, their credentials allow them to teach something that's integrating the different ones, but where their area of expertise and comfort and identity as a science teacher is, that had to take some changing. Our eighth grade teachers have been the most ready to be willing to do that. They're just at a different place. So, they've been excited to do that integration and go forward with it. [For] our seventh grade teachers, life science seems to be something that is emotionally hard to let go of. They've had a mourning process.*

Early Implementer districts have long recognized these issues. They are actively providing professional development on science content through Cadre sessions described above or district professional development sessions, and providing teachers with resources and materials on the content they are teaching. Further, the NGSS require students to take more ownership of what they are doing and learning, and this puts less burden on teachers to "know all of the answers." Because of this shift in science instruction overall, middle grade teachers making the transition to the integrated model should approach it as a chance to learn new content *with* their students, rather than needing to learn every detail of some new content *before* they can teach it.

While many middle grade teachers have expressed some discomfort with the new content that the integrated model of science instruction asks them to teach, many more are now seeing the benefits of integration and how they outweigh the challenges.

Special Challenges for Teachers with Block Courses or Self-Contained Classes

It is most often teachers in grade 6 who have a classroom configuration other than science being taught as a separate class (see Table 4); however, there are some teachers in grades 7 and even 8 who also face this challenge. This configuration challenge exists in most districts, but it surfaced more strongly in four of the eight districts participating in the Initiative. Evaluators encountered an additional challenge: some middle schools in some districts, or certain schools within a district, only allowed science to be taught for half the school year in grade 6.

All middle grade teachers are affected when configuration challenges exist, as illustrated by this grade 8 teacher who described feeling that he had been "triaging" for the last three years:

> *Incoming 8th graders haven't really had any science until my class . . . it isn't until*

Table 4. Comparison of grade 6–8 teachers' science class configuration, by grade level

Grade level	Self-contained class-room (all subjects) *Teacher Leaders*	Self-contained class-room (all subjects) *Expansion teachers*	Multiple science-only classes *Teacher Leaders*	Multiple science-only classes *Expansion teachers*	Block-type courses (science and another subject) *Teacher Leaders*	Block-type courses (science and another subject) *Expansion teachers*
Grade 6	47%	24%	16%	28%	33%	31%
Grade 7	8%	0%	63%	67%	19%	10%
Grade 8	7%	0%	78%	65%	11%	12%

Source: Responses of middle school teachers to the Classroom Science Teaching Survey (N=111) and Survey for K–8 Science Teachers (N=81) administered by WestEd in 2017–18.

this year [2017–18] that the 6th grade teachers are really doing NGSS with their students . . . . I am compensating for the lack of great NGSS science instruction in earlier grades to help the students gain solid understandings, and so they can still do decent on the state test.

In an open-ended survey question, 37 percent of Teacher Leaders reported being worried about students' science knowledge from prior grades as one of their biggest challenges for implementing integrated science.

Teachers in grades 6 or other grades having configuration challenges will need extra support, as illustrated by these candid comments from one such Teacher Leader in grade 6:

Not everyone in 6th grade is even doing science, let alone integration, and it is done differently at all of the different elementary sites because some teach blocks, some teach all subjects. The middle school [grade 7–8] teachers are finding that students might be getting some of the same things at multiple years.

Teachers in this Teacher Leader's district have expressed a desire to meet in grades 6–8, but it is a "logistical nightmare" trying to get all of the disparate grade 6 teachers in a single meeting alongside their grade 7 and 8 colleagues.

A grade 6 expansion teacher from a different district indicated similar issues with implementing integrated science instruction. At a professional learning event on the integrated model, her district Science Coordinator emphasized how important it was that grade 6 transition to integrated science, which required coordinating with grades 7 and 8. However, when grade 6 is located in several elementary schools feeding a grade 7–8 middle school, it is even more problematic for teachers to convene, communicate, and collaborate across the 6–8 grade band to achieve vertical alignment, or to assist each other with lesson planning and instructional strategies.

Recommendations for Administrator Support of Integration

Based on the survey and interview findings described throughout this report, it is evident that helping teachers shift to an integrated approach to science instruction is a complicated and time-consuming endeavor. School and district administrators play a critical role in formulating a plan to transition to integrated science, helping to align curriculum across grades, and supporting teachers throughout the process.

Informed by this report's findings, we offer some key recommendations for how administrators can support integrated science instruction in their schools and districts.

- **Gain a basic understanding of integration.** Reading this report may get administrators much of the way. They can go the next step by developing an understanding of "good" phenomena for integration. As noted earlier, this and other Initiative strategies or activities mentioned in this report are more fully described in a prior report, *Next Generation Science Standards in Practice: Tools and Processes Used by California NGSS Early Implementers.*
- **Advocate science integration.** Principals should encourage integrating science not just because their school or district has adopted the state's integrated model, but because it promotes better science learning for students!
- **Develop a multi-year transition plan.** It's not possible to switch from the discipline-specific model to the integrated model instantaneously. Districts and/or schools need their teachers to collaboratively map out how content will be shifted among grades 6–8 over several years.
- **Provide professional development.** Districts and site administrators need to provide professional development for teachers to learn NGSS teaching, including integration. Local higher education faculty could be helpful resources for helping teachers understand content in sciences and engineering that may be less familiar to them.
- **Don't count on seeing integration during just a single class observation.** It generally takes the arc of a full science unit to integrate multiple disciplines; a given lesson period is likely to be mostly focused on a single discipline.
- **Provide time, circumstances, and the expectation for substantial collaboration.** Teachers need you to expect and support their active and substantial collaboration among grades 6, 7, and 8 to achieve a sound vertical alignment across the grades. Collaboration is also needed for horizontal alignment among teachers at the same grade level. Counting on the minimal substantive time available during regular science department meetings will not even come close to what is needed.

- **Provide time both to create model instructional units and to become familiar with, evaluate, and adapt any new materials.** As described in this report, teachers will need to forge new integrated units and lessons, particularly in the current absence of instructional materials that thoughtfully incorporate integration of the sciences. For any districts that soon acquire new science instructional materials under the current California adoption, avoid the common trap of thinking that merely having teachers participate in professional development focused on rolling out the materials will adequately prepare them for implementing them. Teachers will need additional time to substantially prepare for using the new materials effectively, and, possibly, for adapting them to more strongly address NGSS teaching. Teachers using open source materials also need time to evaluate materials for their NGSS appropriateness and adapting them for that purpose, as needed.

- **Facilitate the shifting of supplies, facilities, and equipment, if needed.** Teachers may be reluctant to not only shift the content they teach to another teacher and grade, but also to let go of the "stuff" those teachers will need for teaching hands-on science.

- **Shift all classes to science-only courses with science teachers.** Block courses (in which science is taught along with another subject) and self-contained classes (in which all subjects are taught) — which are most typical in grade 6 — present significant roadblocks to implementing an integrated approach to science instruction. These configurations are affecting science in all the middle grades because of vertical alignment issues, which are accentuated when grade 6 is located in a different school from grades 7–8 and resources for hands-on science instruction need to be shifted among all three grades. But this change could well be beyond administrators' authority. If you do have configurations other than science-only courses, know that these teachers will need even more support and collaboration than teachers of science-only courses.

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Appendix A. Select Survey Questions from the Evaluation

Survey for K–8 Science Teachers (2017–18)

1. During the 2017–2018 school year, what percentage of your science instruction (including stand-alone science and science integrated with other subjects) addressed content from the following science disciplines? Please make sure your entries add to 100.
   a. Physical
   b. Earth & Space Science
   c. Life Science
2. How well would you say you understand the following? How to address more than one science discipline (i.e., Earth/space, life, physical) in a science unit.
3. During the 2017–2018 school year, how often did you do the following in your own classroom? Address more than one science discipline (i.e., Earth/space, life, physical) in a science unit.

Classroom Science Teaching Survey (2016–17 & 2017–18)

1. During the 2016–2017/2017–2018 school year, what percentage of your science instruction (including stand-alone science and science integrated with other subjects) included content from the following science disciplines? Please make sure your entries add to 100.
   a. Physical
   b. Earth & Space Science
   c. Life Science

   Is there anything we should know in order to understand your response to the question above?
2. Which description below best describes your science instruction (including stand-alone science and science integrated with other subjects) during the 2016–2017 school year?
   a. Discipline-Specific (teaching only one science discipline during the school year: Physical, Earth & Space, or Life)
   b. Coordinated (teaching multiple science disciplines during the school year, with a majority of instruction focused on one discipline at a time)
   c. Integrated (having a majority of instruction and/or units throughout the school year integrating two or more science disciplines)
3. What percentage of your science instruction (including stand-alone science and science integrated with other subjects) during the 2016–2017 school year would you consider to be "integrated" (integrates two or more science disciplines: Earth & Space, Life, and/or Physical Science)?

4. To what extent has the Early Implementation Initiative (EII) enhanced your ability to integrate the sciences (Physical, Earth & Space, and/or Life)?

5. Please identify up to THREE of your biggest challenge(s) for transitioning to the CA Preferred Integrated Model for science.

Teacher Leadership Survey (2017–18)

1. How well would you say you understand the following? How to address more than one science discipline (i.e., Earth/space, life, physical) in a science unit.

Core Administrator Leadership Survey (2017–18)

1. How well would you say you understand the following? How to address more than one science discipline (i.e., Earth/space, life, physical) in a science unit.

2. How well would you say you understand the following? The CA "Preferred Integrated Model" for middle school.

3. Which description below best describes the science instruction of a majority of your science teachers during the 2017–2018 school year.

   a. Discipline-Specific (teaching only one science discipline during the school year: Physical, Earth & Space, or Life)

   b. Coordinated (teaching multiple science disciplines during the school year, with a majority of instruction focused on one discipline at a time)

   c. Integrated (having a majority of instruction and/or units throughout the school year integrating two or more science disciplines)

Survey for Principals (2017–18)

1. How well would you say you understand the following? How to address more than one science discipline (i.e., Earth/space, life, physical) in a science unit.

2. How well would you say you understand the following? The CA "Preferred Integrated Model" for middle school.

Appendix B. Select Interview Questions from the Evaluation

CA K–8 NGSS Early Implementation Initiative Evaluation: EII Administrator Interview #1 Protocol: May-June 2017

1. (FOR 6-8 ONLY, including admins of elementary school that include 6th grade) Where would you say the district (or your school) is in the process of transitioning to the Integrated Model?
   a. What have been the biggest barriers or challenges? (probe re 6th grade)
   b. What still needs to be done?

CA K–8 NGSS Early Implementation Initiative Evaluation: EII Administrator Interview #2 Protocol: June-July 2018

1. (FOR 6-8 ONLY, including admins of elementary school that include 6th grade) Where would you say the district (or your school) is in the process of transitioning to the Integrated Model?
   a. What have been the biggest barriers or challenges?
   b. What still needs to be done?

CA K–8 NGSS Early Implementation Initiative Evaluation: Case Study Teacher Interview #2 (End of Year) Protocol: June 2017

Part 2: Integrating NGSS Science with ELA & Environmental Education (& MS Integrated Science Model)

This next set of questions asks about the integration of NGSS science with Common Core and English/Language Arts. [MIDDLE SCHOOL ONLY:] This part also asks about your experience with the MS Integrated Science Model.

1. **[MIDDLE SCHOOL ONLY]** How would you describe the integration of the science disciplines in your teaching since our last interview?
2. **[MIDDLE SCHOOL ONLY]** Can you please describe (or send me) an example of a lesson or unit that you taught in the last few months that integrated 2 or more science disciplines?

3. [**MIDDLE SCHOOL ONLY**] Because of the Integrated Model, do you need to teach some science content that you have not taught before?
    a. **Probe:** If so, what content? How do you feel about this? How did you or how are you preparing for this?
4. Are you following a scope and sequence that lays out what you're doing/not doing in your grade level?
    a. **Probe:** If so, where did it come from? Are other teachers in your school/district following this as well? *(Be sure to get a copy of whatever they have)*

CA K–8 NGSS Early Implementation Initiative Evaluation: Case Study Teacher Interview #3 (Fall 2017) Protocol: Nov-Dec 2017

Part 3: Middle School Integrated Science Model

This next set of questions asks about your experience with the MS Integrated Science Model.

1. [**MIDDLE SCHOOL ONLY**] Does your school or district have a transition plan for going from the discipline-specific model to the integrated model?
    a. **Probe:** If so, is it being followed? Is it on schedule?
    b. Where would you say your school is in the transition process on a scale from 1–10 (with 1 being not integrated at all, and 10 being completely integrated)?
        i. What have you observed that leads you to that estimate?
    c. What are the biggest barriers to integration? OR What do you, as a teacher, most need to successfully transition to the integrated model?
2. [**MIDDLE SCHOOL ONLY**] What is the configuration of science in grade 6 at your school? (e.g., part of elementary? Designated subject for a full year/semester only? Block period with another subject?)
    a. Has this configuration changed to address the Integrated Model?
    b. How does this configuration of science in grade 6 affect how students are learning science or how you teach science?
3. [**MIDDLE SCHOOL ONLY**] How would you describe the integration of the science disciplines in your teaching?
    a. Where have you made the most progress toward implementing the integrated model in your classroom? What contributed to that progress?
    b. Would you say your teaching relates more to 1 or 2 disciplines or are all disciplines covered in substantial depth?
    c. What percentage of your lessons/units are "integrated"?
    d. Can you please describe (or send me) an example of a lesson or unit that you taught in the last few months that integrated 2 or more science disciplines?
4. [**MIDDLE SCHOOL ONLY**] Because of the Integrated Model, do you need to teach some science content that you did not teach before NGSS?
    a. **Probe:** If so, what content?

   b. How do you feel about this (e.g., confident, frustrated, interested)? How have you or how are you preparing for this?

5. [**MIDDLE SCHOOL ONLY**] Is integrating the science disciplines or covering less familiar science content something you help other teachers with?

   a. If so, with whom and please describe.

CA K–8 NGSS Early Implementation Initiative Evaluation: Case Study Teacher Interview #4 (End of Year) Protocol: May/June 2018

[Middle School Only] Part 2.5: The Integrated Science Model

We are interested in districts' and teachers' progress toward implementing the California Preferred MS Integrated Science Model.

1. [**MIDDLE SCHOOL ONLY**] What is your understanding or vision of what the integrated model would look like in the classroom if it were fully implemented?

   a. How does what you just described relate to your science instruction during the 2017–2018 school year? (Have you achieved this? To what extent? If not, is it your goal?)

   b. How, if at all, has your understanding of the integrated model changed over the last few years?

2. [**MIDDLE SCHOOL ONLY**] What, if anything, is *supporting* your implementation of the integrated model?

3. [**MIDDLE SCHOOL ONLY**] What, if anything, is *hindering* your implementation of the integrated model?

4. [**MIDDLE SCHOOL ONLY**] Can you please describe (or send me) an example of a learning sequence or unit that you taught in the last few months that integrated 2 or more science disciplines?

CA K–8 NGSS Early Implementation Initiative Evaluation: Middle School Integrated Model Case Study Teacher Interview Protocol: April/May 2017

Teaching

1. What are you teaching now or what have you taught this year that someone would consider integrated? (Specifically **probe** what they have done in the most recent school year.)

   a. Are you teaching more integrated science this year compared to previous years?

      i. If so, what do you attribute this to?

      ii. If so, do you expect this trend to continue? Why or why not?

   b. Do your individual *lessons* often integrate two or more science disciplines or is integration more typically evident at the instructional *unit* level?

   c. How often would you say you teach content that integrates more than one science discipline?

   d. Which disciplines do you integrate most easily and/or most often (e.g., Earth & life are easy to integrate, or physical and engineering are integrated most often in their class)? Why?

2. What is your strategy for developing lessons or units that integrate the science disciplines?

3. Let's talk about the lesson/materials you sent me. Could you please walk me through this lesson/whatever?
    a. Where did this come from?
    b. When did you teach this?
    c. What about this is most relevant to EE?
    d. What about it is most relevant to NGSS?
4. How, if at all, has the Early Implementers Initiative helped you integrate the science disciplines in your instruction?
    a. Are there any tools, strategies, or processes that you've found to be particularly helpful in integrating science instruction?

Support

1. Does your school or district have a plan for implementing the integrated model?
    a. If so, how and how much is that plan being followed? How many teachers are following (to the best of your knowledge)?
2. What are some challenges you've encountered when trying to teach science that integrates the disciplines?
3. What are the most important things a principal or a district can do to support teachers in transitioning to the integrated model?
    a. Which of these things, if any, have you experienced yourself (e.g., supportive principle or district level staff, initiatives, professional development, etc.)?

Student Response to Integrated Instruction

1. How, if at all, are students responding to integrated instruction overall (e.g., student interest, engagement, science understanding, etc.)?
    a. Are ALL students or certain populations responding this way (including boys/girls, minority students, ELLs, students with disabilities, gifted students, special ed students, etc.)?
2. A goal of integration is making science instruction more "authentic" by demonstrating the integrated nature of modern science and highlighting the connections between disciplines. Do you think that your students are able to see and understand these connections between disciplines and are engaging in more "authentic" science?

K–8 NGSS Early Implementation Initiative: Project Director Interview Protocol: Nov-Dec 2016

1. Briefly, what is the status of the transition to the Integrated Model in (district)?
2. Are there any teachers who you know of who are or have been able to really integrate the science disciplines in instruction? Are you aware of even a single unit or lesson that really exemplifies this kind of integrated instruction?

K–8 NGSS Early Implementation Initiative: Project Director Interview #3 Protocol: March 2017

Part 4: Teacher Credentials and the MS Integrated Model

It has come to our attention that the switch to NGSS and the move to the Integrated model for middle grades can present issues related to teacher credentialing. We want to understand more clearly how these changes in credentialing are affecting districts, schools, and teachers.

1. How many teachers (if any) are teaching outside of their credential areas?

2. Are there credential issues you are running into in the middle grades (with the change to the integrated model)?
   a. **Probe:** Does your district have 6th grade teachers who teach science as well as other subjects? Do they have elementary or secondary credentials? If secondary, are their credentials in science (or another subject)? If elementary, do they have supplemental authorizations (for science? For another subject?)?
3. To what extent at this point do you feel middle school teachers in the district are integrating the sciences each year?

K–8 NGSS Early Implementation Initiative: Project Director Interview #4: Nov 2017

Part 2: The integrated model

1. Does the district have a clear plan for transitioning to the Middle School Integrated Model?
   a. Is it in writing and has it been shared with all middle schools? (If so, may I please get a copy?)
      i. Can you briefly describe the plan for me?
      ii. Has it been followed? Is it on schedule?
2. What percentage of your middle schools have fully transitioned to the middle school integrated model?
   a. How much variability would you say there is across middle schools in the district?
   b. How much variability would you say there is across middle school teachers?
3. Would you say that middle school teachers are more embracing or struggling with the new content they're supposed to teach?
   a. What evidence do you have for your answer?
   b. Have you noticed changes in how middle school lessons are designed?
      i. Are you basing your answer on your observation of TLCs or other classroom instruction?
4. What are the most important things a district or school can do to support teachers through this transition?
5. What is the configuration of science in grade 6 at your school/district? (Part of elementary? Designated subject for a full year/semester only? Block period with another subject?)
6. We are looking for examples of what integrated instruction looks like in middle school. Which teachers would you recommend we contact?

Bechtel NGSS — Regional Director Interview #2: June 2015

1. Is this district moving — or planning to move — toward an integrated middle school model? (If yes, ask: Can you describe how, if at all, the Initiative is playing a role in this?)

K–8 NGSS Early Implementation Initiative: Regional Director Interview #4: January 2018

Part 3: The integrated model

1. What, if any, are the most significant obstacles the district is facing in its transition to the integrated model?
2. What, if any, changes have you noticed in how middle school lessons are designed in the TLCs?
   a. **Probe:** Have you noticed that the lessons/learning sequences more often or more extensively integrate two or more science disciplines?
   b. Have you observed integrated middle school lessons in the district outside of the TLCs?
   c. Are there any teachers you know of who are further along in achieving MS integration in their lessons?

What do you think are the most important things a district or school can do to facilitate the transition to the middle school integrated model?

Appendix C. Extended Version of One Classroom Teaching Vignette

Observed Grade 6 Lesson: Surviving on Mars

This expanded version of the observed grade 6 lesson presented in the body of the report is included here as an example of a more complete NGSS lesson sequence lasting approximately three weeks. While the observed lesson is an excellent example of instruction integrating the physical, Earth and space, and life sciences as well as engineering, the expanded lesson sequence below stands to illustrate for readers more of the shifts in pedagogy that the NGSS call for. NGSS lesson sequences can be extensive. In fact, the reader is encouraged to note that this expanded lesson sequence is not necessarily a standalone unit. As the Teacher Leader explains, this lesson sequence was itself integrated with another related unit on ocean currents. This exemplifies NGSS instruction: the storyline of instruction typically connects one line of inquiry to other related scientific concepts, often based, when possible, on student interest or student questions.

A grade 6 teacher who teaches all subjects at her elementary school has been a part of the Early Implementers Initiative since summer 2014. She had a passion in college for history and entered the Initiative with minimal science background. At the first Summer Institute, the Content Cadre engaged her in a lesson sequence on what it would take for humans to survive on Mars. Since then, she says, "We've been revising it a little more each year, trying to make it more integrated with other learning sequences that we've been building over the last four years. And it's much longer and more involved than the Cadre could do in a week." She is pleased with the result, a lesson sequence that authentically incorporates not only the physical, Earth and space, and life sciences, but also engineering design. This year, for the first time, she plans to connect the data collected in this lesson with her math instruction.

Here, she gives an overview of the "story line" of the full lesson sequence:

> *We did lots of investigations about heat energy and that was kind of integrated into a unit about ocean currents. So, it's kind of a combination of physical and Earth science, because the storyline is like how ocean currents move and how these patterns are created through thermal energy transfer and also the water cycle. And then their little [model] habitat should include those two things and life science too for survival on Mars. This engineering challenge is them taking their science knowledge and applying it to a new scenario.*

Next year she is considering another engineering activity that will link directly to ocean currents and encompass human impact:

> ***We're trying to figure out how to bring [human impact] into our ocean currents more, with maybe doing the Pacific garbage patch, and then I've seen where kids create ocean trash collectors. I want the engineering to come out of something more authentic.***

On the board the teacher has written, "Write down everything you know about what living things need to survive. Use all the science knowledge you learned this year to do this." To make sure that all students have something to share, students are instructed to take a few minutes to write their ideas in their science notebooks. Then the teacher asks them to share their ideas, first at their tables, and then as a class. Some of what students share includes:

> "Oxygen, CO_2 if you're a plant."
>
> "Water."
>
> "Trees."
>
> "Shelter."
>
> "Air."
>
> "Gravity."
>
> "Education."
>
> "Clothes."
>
> "Atmosphere."
>
> "Vitamins."
>
> "Weather."
>
> "Heat."
>
> "Education."
>
> "A heart. . .Organs, blood, bones, and all that stuff."
>
> "Light."
>
> "Speech."

The teacher asks students to discuss in their small groups the items that represent the absolute bare minimum that humans need to survive. Then, as students share out their ideas about what is absolutely necessary, the teacher engages with them to elicit deeper thinking about some items through questioning strategies rather than correcting them or offering her own knowledge. Eventually the class settles on the following list of what humans need to survive on Earth: Water, food, oxygen, and "shelter, especially if you're in an area that is either hot or cold."

The teacher then shows a slide introducing students to the topic they will be engaged in for the next three weeks. It is an engineering design challenge: to address the problem of over-crowding on Earth, NASA needs engineers to design a habitat that can support humans on Mars (see Figure C1). Students will be designing, building, and testing model habitats for Mars.

Next, because this class has not done much engineering, the teacher puts on screen the Engineering Design Process, shown in Figure C2.

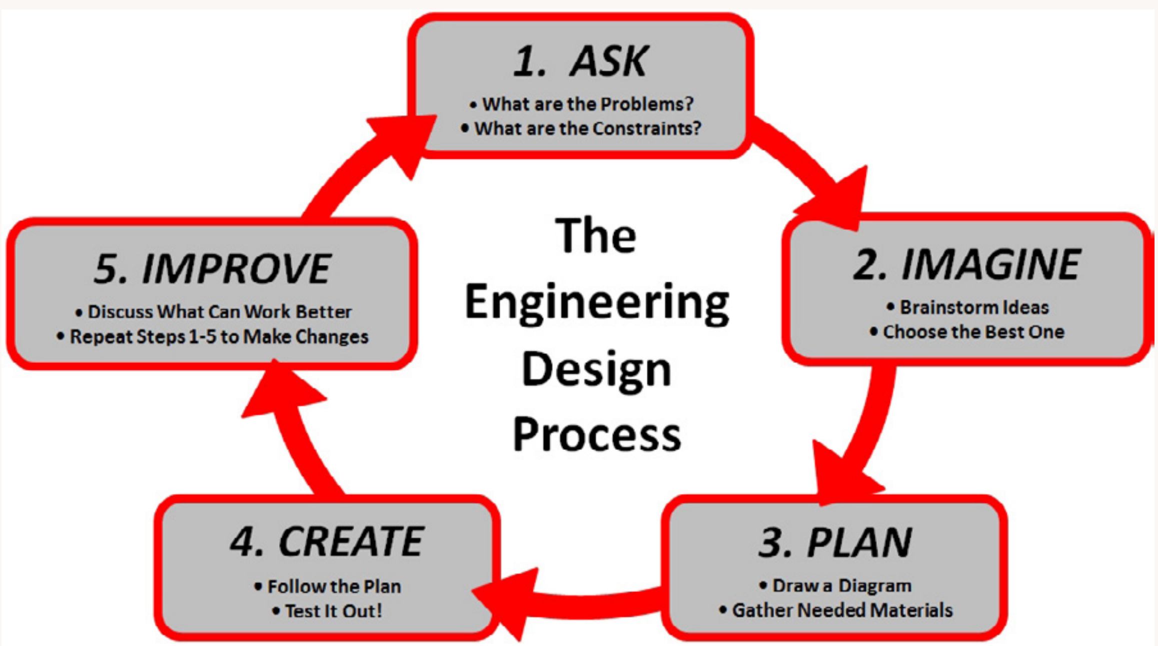
She tells students that over the next couple of weeks, they will be engaging in the full engineering design process to solve a problem: "Earth is becoming overcrowded, and engineers are needed to create habitats for human beings on Mars." She explains that they will work in their groups to "engineer a model of a habitat to support two humans on Mars," using a clear container and materials they will test and choose.

The teacher prompts students to think and record in their notebooks what they need to

Figure C1. Introducing the design challenge

Source: Teacher's slide shown during a lesson observed by the evaluation team in spring 2018 (Larwin & Orwig, 2016).

Figure C2. The engineering design process



Source: Grade 6 teacher's slide shown during a lesson observed by the evaluation team in spring 2018 (source: https://www.mrflemingscience.com/engineering-design-process.html).

Figure C3. Contrasting conditions on Mars and Earth

Mars-Comparison Chart

	Mars	Earth
Atmosphere	Carbon Dioxide 95% Nitrogen 3% Argon 2% Oxygen 0.13% Water Vapor 0.03% Nitric Oxide 0.01%	Nitrogen 77% Oxygen 21% Argon 1% Carbon Dioxide 0.03%
Distance from Sun	142,633,260 miles	149,597,891 miles
Length of day	24 hours 37 minutes	24 hours
Length of year	687 days	365 days
Surface temperature	-81°F	57°F

What materials do you think you need to build your Mars habitat?

*Remember they need to be easily attainable or something you have already seen in a science investigation.

Source: Teacher's slide shown during a lesson observed by the evaluation team in spring 2018.

know or think about when designing their Mars habitat. Students come up with a number of considerations:

> "Temperature. How hot or cold it gets there."
>
> "What is the average temperature? What's the weather like?"
>
> "How far from the sun, in miles?"
>
> "Do they have any protective layers?"
>
> "Gravity?"
>
> "How big is Mars?"
>
> "Obviously, Mars doesn't have water and stuff, so where are we going to get water from?"
>
> "What is the age of people we're sending? Because that makes a difference."
>
> "Is there soil? And if there is, what type?"
>
> "Will materials melt?"
>
> "What is the number of people we are sending?"
>
> "How will materials act in Mars' gravity?"
>
> "Does Mars have any sort of wind or weather?"

The class is presented with data about Mars and Earth (see Figure C3), which they use to inform their decisions on what is needed for a habitat on Mars. Students discuss in their small groups the items that represent the absolute bare minimum that humans need to survive. After a lengthy debate and a process of elimination of less critical factors, the class decides that if a habitat maintains a steady temperature and harnesses the water cycle, then it will be successful on Mars. These two factors are their criteria for success.

She tells the students, "Because of what we have been learning this year, you have tons of knowledge to help you with these two areas." They

Figure C4. List of materials available for Mars habitat design lesson

Materials

Limited

- black garbage bag (1 square piece)
- white paper
- black paper
- bark
- sand
- rocks
- aluminum foil
- potting soil

TOOLS:

2 liter bottle or jar
Tape
1 piece Saran wrap
5 Popsicle sticks
Small measuring cup (1)
Water (at most one cup)

Source: Teacher's slide shown during a lesson observed by the evaluation team in spring 2018.

also discuss the constraints that they must work within, especially while testing their designs, such as the fact that gravity, the atmosphere, and the soil are different on Mars.

The teacher tells the group that their habitats will be enclosed in sealable, clear containers, such as an empty soda bottle, and reminds them that they are limited by other constraints, including budget. ("We can't call up NASA and ask for fancy equipment!") With that in mind, the teacher asks students to come up with some ideas for materials they may need to build their habitat models. She writes down all of the "doable" materials they ask for (see Figure C4) with the intention of getting them in time to start building and testing. Many items she already has on hand. She does not want to limit her students' creative thinking by simply offering a list, in case they came up with ideas she had not anticipated. This approach, she hopes, will increase the ownership students have in designing their habitats.

The rest of the class period is guided by the two questions:

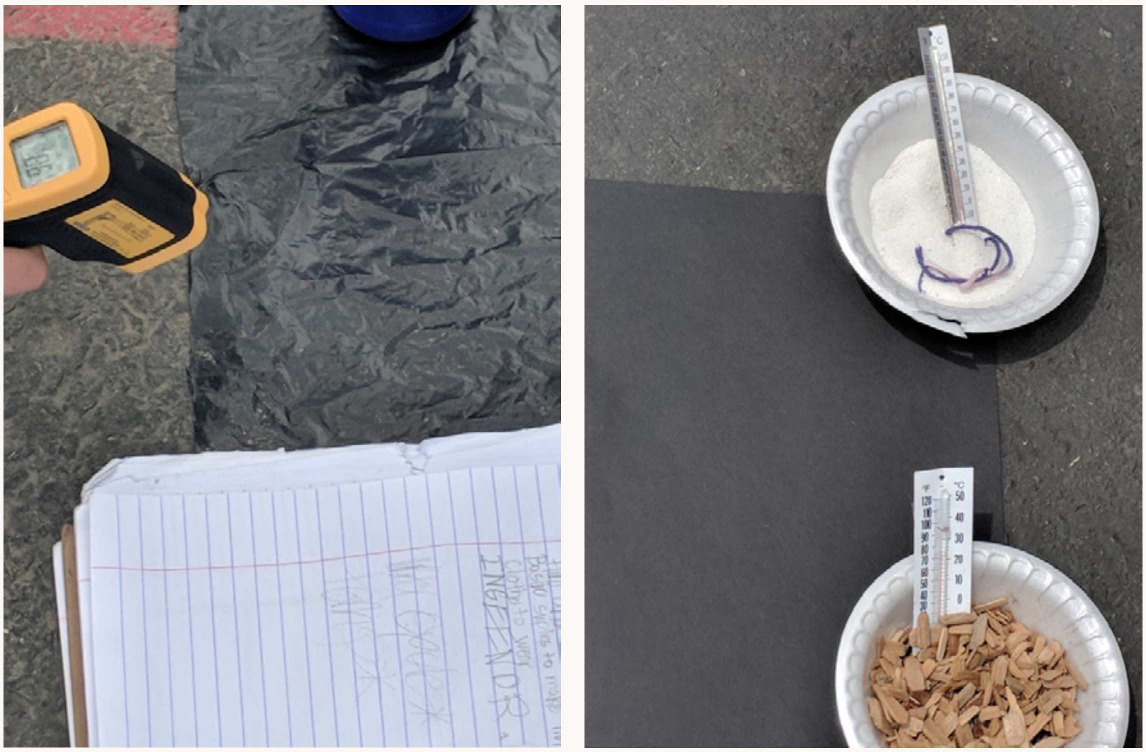
- Which materials work best for sustaining a constant temperature?
- Which materials could be used to create the water cycle inside your jar or bottle?

Working in eight groups, one for each material type, the students record the properties they observe and evaluate whether they think their material would be appropriate to sustain temperature and harness the water cycle (see Figure C5). Each group records the initial temperature of their material and then the temperature after 20 minutes in the sun. Before the lesson ends, students return to the classroom and share their findings with the rest of the class.

Later, using the collective class data as evidence, each student will choose three of the materials to use in their habitat designs. The teacher explains the students' use of the various materials:

> *I will be looking for them to make a connection between the change in temperature and what materials to choose for their habitats. And then in a few days, they'll draw a model. They'll need to have a scientific reason based on evidence for using black paper over white paper or whatever.*

Figure C5. Testing materials for Mars habitat engineering design lesson



Source: Images from a grade 6 science lesson observed by the evaluation team in spring 2018.
Note: In the left-side image, students use a temperature gun on a sheet of black plastic. In the right-side image, thermometers are used to measure the temperatures of two other building materials (sand and wood chips/bark). Rate and degree of temperature change are recorded first as materials sit in the sun and then when they are brought back into the classroom.

As part of their designs, students will predict how the materials will enable the habitat to sustain a stable temperature and harness the water cycle. Their written habitat models must contain information about both the water cycle and energy transfer, including conduction, radiation, and convection. The class will read an article about these concepts and about "radiation" and "insulation," and students will discuss how these physical science concepts play a role in the ability of their habitat to sustain life. The teacher notes that "I will be looking for them to understand that even though it's really cold outside, Mars is still getting radiation. So, the goal is to get this radiation, and use it to help the humans inside whatever they build."

Finally, the groups will build, test, and revise, their designs. As they progress, the teacher will convene the class a few times to allow groups to learn from one another's experiences and findings. Finally, students will create a redesigned habitat that can sustain a stable temperature and harness the water cycle. The final habitat will be larger and more complex, using up to seven different materials, which students will test to determine adherence to all of the agreed-upon criteria and constraints.

When interviewed after the lesson, the teacher was pleased that students were making connections to previous investigations they had done:

The students realized it was better to have water than air to maintain temperature. We have done so many tests on water and ice and heat energy transfer. They know that water absorbs heat very slowly, but once it catches it, it holds onto it longer… They realized if they poured the whole glass of water in there, it would actually help their habitat stay warmer as well, which I thought was really cool.

We did heating with a heat lamp, comparing water versus air in a bottle, so they saw that the air got really hot really fast, but then the air [temperature] dropped almost instantly (when the heat lamp was removed). The students remembered that investigation and were like, "Oh, so I want less airspace." We had an array of objects for them to choose from, and the students chose the smaller bottles because they knew there would be less air. They filled it as full as they could with water and dirt and sand or whatever and had very little air space.

Though much of the science in this lesson sequence on engineering a Mars habitat addresses physical science (e.g., heat transfer) and Earth and space science (e.g., the water cycle, weather and temperature, conditions on Mars), students were also addressing some relevant life science concepts (e.g., conditions needed for survival). Students were also engaging in a fully three-dimensional experience by covering many of the Science and Engineering Practices, including asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, and designing solutions; as well as some Crosscutting Concepts, such as energy and matter, systems and system models, patterns, and stability and change. This lesson sequence also highlights how teachers who have limited experience or background in science or engineering can become effective science and engineering teachers, fully capable of creating and teaching integrated science lessons.

NGSS EARLY IMPLEMENTERS
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Making Middle School Science Whole

Transitioning to an Integrated Approach to Science Instruction

EVALUATION REPORT 5

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