High Hopes – Few Opportunities

The Status of Elementary Science Education in California

STRENGTHENING **SCIENCE EDUCATION** IN CALIFORNIA

THE CENTER FOR THE FUTURE OF
Teaching & Learning
at WestEd

Research conducted by:
The Lawrence Hall of Science at
University of California, Berkeley
and SRI International

High Hopes – Few Opportunities: The Status of Science Education in California summarizes new and extensive research examining the status of science education in the state's classrooms and schools. The research was conducted in support of Strengthening Science Education in California, a research, policy and communications initiative that brings together educators, researchers, and others to examine the status of science teaching and learning and to develop recommendations for improving science education in California. Partners in this initiative include the Center for the Future of Teaching and Learning at WestEd, the University of California, Berkeley's Lawrence Hall of Science, SRI International, Belden Russonello & Stewart, Stone's Throw Communications and Inverness Research.

The findings in this report are based on the results of surveys conducted in 2010 and 2011 of elementary and middle school teachers and principals, as well as school district leaders in communities across California. These findings are enhanced by the analysis of secondary research data on students and teachers, and case studies of science education efforts in school districts in California.

High Hopes – Few Opportunities: The Status of Science Education in California is the second in a series of research reports conducted and published by partners in the Strengthening Science Education in California Initiative. Following initial public opinion research showing Californians believe that high quality science education should be a top priority for the state's schools, this new research examines the realities of science education in classrooms, schools and communities. The results reveal a stark gap between the rhetoric about the importance of science education, and the capacity of teachers and schools to provide students with high quality learning opportunities in science. We believe that accurately understanding the realities of science education is critical to efforts to strengthen scientific literacy in our state. Our intent is to share the findings of this research, as well as our subsequent research efforts, with educators, policymakers, and the public in ways that stir debate and inform decision making which results in more and better science education for the students of California.

This report was produced by The Center for the Future of Teaching and Learning at WestEd in consultation with our partners:

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EXECUTIVE SUMMARY

A consensus has emerged in the United States and in California on the need for all students to graduate from high school better prepared for the world of postsecondary education, work, and citizenship. The globalization of the economy and continued technological advances mean that requirements for all jobs are constantly evolving. Our greatest societal challenges, from climate change to the lack of an adequate water supply to public health, will require greater innovation and scientific know-how. Those countries and states that respond with the best-prepared workforce and citizenry will assume economic leadership.

This report addresses how well California is doing to prepare its young people for the evolving economy and societal challenges. Specifically, it describes the status of science teaching and learning in California public elementary schools. This study was conducted in support of *Strengthening Science Education in California*, a research, policy and communications initiative that explores the strength of science teaching and learning and offers recommendations for improving science education in California. Partners in this initiative include the Center for the Future of Teaching and Learning at WestEd; the Lawrence Hall of Science at the University of California, Berkeley; SRI International; Belden Russonello & Stewart; Stone's Throw Communications; and Inverness Research.

The report synthesizes findings from multiple sources of data collected during 2010–11: surveys of district administrators, elementary school principals, and elementary school teachers; case studies of elementary schools; and data available through existing statewide datasets. It is one in a series of reports designed to provide timely and actionable information about the status of science education in California and to identify ways it can be strengthened. The central finding of this report points to the need for significant improvement: **children rarely encounter high-quality science learning opportunities in California elementary schools because the conditions that would support them are rarely in place.**

Science Learning in California Classrooms

Few children have the opportunity to engage in high-quality science learning in California elementary schools. Only about 10% of the students in the state experience science instruction that regularly engages them in the practices of science—the vision of quality science learning offered by the National Research Council (NRC) (2007, 2011). Moreover, because of the limited time spent on science in California classrooms, elementary school students receive little exposure to any type of science instruction. Disturbingly, 40% of elementary teachers in grades K–5 in our survey reported that their students receive 60 minutes or less of science instruction per week.

Accountability requirements explain in part the lack of time for elementary science. Despite their desire to teach science, teachers are under pressure to concentrate on English language arts and mathematics, which limits the amount of time available for science and other subjects. Yet some teachers, schools, and districts have found ways to bring science into the school day. Some do so by integrating sciences with other content areas, most often with English language arts. Teachers who frequently integrated science with other subjects offered science an average of 130 minutes a week, compared with an average of 94 minutes per week for teachers who rarely or never integrated science.

The Conditions That Shape Science Learning Opportunities

Several factors influence the quality of science learning opportunities: teachers, instructional materials, and assessments of student progress.

Teachers. Few elementary school teachers have strong science backgrounds, and the support they receive to teach science once they are in the profession is minimal. Although almost 90% of teachers surveyed felt very prepared to teach English language arts and mathematics, only about one third felt very prepared to teach science. Yet opportunities for professional development for elementary school teachers are scarce: More than 85% have not received any science-related professional development in the last 3 years. Teachers, principals, and district administrators all acknowledged that this lack of professional development opportunities is a challenge to providing science instruction in elementary schools.

Instructional materials and facilities. Elementary school teachers want materials that are engaging and offer opportunities for their students to do hands-on science activities. Teachers report limited funds for equipment and supplies (66%) and lack of facilities (56%) present a major or moderate challenge to providing science instruction. Unfortunately, teachers in schools serving higher percentages of students in poverty were more likely to report lack of facilities as a major challenge to providing science instruction than were teachers in more affluent schools.

Assessing student progress. California administers only one statewide science assessment at the elementary level (in fifth grade), and it does not capture all the important learning outcomes related to science. Few schools or districts have established local systems to monitor student progress and thus teachers have no systematic data on students' science knowledge until they have been in elementary school for 6 years (K–5). Sixty-six percent of California elementary teachers reported that they receive little to no support in assessing their students' science learning. Unfortunately, teachers in elementary schools serving higher percentages of students in poverty were more likely to report receiving limited or no support for assessing their students' science learning than teachers in elementary schools serving lower percentages of students in poverty.

Supporting Science Learning

Leadership. California principals value elementary science education and believe it should begin early. Virtually all (99%) California elementary school principals believe that providing all students a strong background in science is very important. Furthermore, almost all principals (92%) believe that science education should begin in kindergarten. Yet districts and schools lack a support infrastructure for improving science learning in elementary schools. More than half of California districts (55%) and schools (54%) have not had any significant elementary science education initiatives in the past 5 years. Even more disturbing, elementary principals in the state's poorest schools were less likely to report that their schools have had significant science initiatives in the past 5 years than principals in more affluent schools.

Overall, district support for elementary science is limited. Over 60% of districts have no district staff dedicated to elementary science. Limited district support for elementary science translates into no access to science specialists or coaches for most elementary schools. Seventy-five percent of elementary principals reported that their schools do not have access to a science specialist or coach. Yet some principals and district administrators demonstrated strong support for elementary science learning by establishing a coherent vision for high-quality instruction and aligning district and school policies and practices with that vision. To be successful in these efforts, principals and district administrators require opportunities to build their own capacity to promote and enact that vision.

Resources and support. California's economic crisis has resulted in deep cuts to education, leaving limited funds to support teaching and learning. The lack of resources hits science particularly hard. In this climate, schools and districts often seek external resources to support subject areas such as science. But too few schools and districts have access to such funding sources. Most schools and districts do not receive fiscal support for elementary science from external funders. Seventy percent of districts and 72% of schools did not receive funds from external funders to support elementary science. The survey results showed that districts and schools were more successful accessing services than funds from a variety of sources outside the district. Sixty-three percent of districts and 48% of school principals reported receiving support for elementary science from external organizations. County offices of education, informal learning institutions (e.g., science centers, zoos), and institutions of higher education were the organizations serving the largest percentages of districts and schools.

Conclusion

California citizens, parents, and educators recognize the importance of education that prepares all students for careers and college. However, the California education system is far from meeting these ideals. Students do not have the opportunities they need to participate in high-quality science learning experiences because the conditions for doing so rarely exist. California needs but does not have a coherent system that enables teachers and schools to consistently provide students with such experiences.

Over the past decade, the infrastructure for supporting science education in California has eroded significantly. As a whole, California needs a new road map for supporting science learning in public schools. Strengthening science education must be a priority.

CHAPTER 1
THE IMPORTANCE OF SCIENCE EDUCATION

A consensus has emerged in the United States and in California on the need for all students to graduate from high school better prepared for the world of postsecondary education, work, and citizenship. The globalization of the economy and continued technological advances mean that requirements for all jobs are constantly evolving. Our greatest societal challenges, from climate change to the lack of an adequate water supply to public health, will require greater innovation and scientific know-how. Those countries and states that respond with the best-prepared workforce and citizenry will assume economic leadership.

The Challenge: Strengthening Science Education

Given the nature of the evolving economy and societal challenges, science is a critical area of K–12 schooling. Yet, results from recent assessments provide evidence that children are receiving an inadequate science education in California schools. On the most recent fourth-grade National Assessment of Educational Progress (NAEP) science assessment, California students performed at the lowest level nationally along with Arizona, Mississippi, and Hawaii (U.S. Department of Education, 2009). More alarming, fewer than 10% of California's African American and Hispanic fourth-graders are proficient on NAEP's science assessment, compared with 41% and 45% of their white and Asian peers, respectively (U.S. Department of Education, 2009). Although scores on the California Standards Test (CST) in science have risen over the past few years, these gaps among ethnic groups persist on the state exam. Seventy-seven percent of white students performed at proficient or above on the fifth-grade science CST in 2011, as compared with 45% of Hispanic or Latino students and students classified as economically disadvantaged and 43% of African American students.

On the national level, the President's Council of Advisors on Science and Technology (PCAST) concluded that the U.S. response to the challenges of the 21st century "will be determined…by the effectiveness of science, technology, engineering, and mathematics (STEM) education" (PCAST, 2010). These experts' opinion is echoed in the day-to-day thinking of California citizens, who are convinced that science education is the key to the future of the state. Consider the following (Belden, Lien, & Nelson-Dusek, 2010):

- Three quarters (74%) of Californians are convinced that science should be a higher priority for California schools because it keeps both the United States and California at the forefront of technology and innovation.

- Another 7 in 10 (69%) are persuaded that science helps young people (1) compete in the global marketplace and (2) become engaged citizens.
- Sixty-two percent believe that making science a higher priority will attract industry to the state and provide a gateway to higher paying jobs.

The Context: California

California has a specific educational context for science learning, the *Science Framework for California Public Schools*, which includes the *Science Content Standards* and *Guidelines for Selecting Instructional Materials* (Curriculum Development and Supplemental Materials Commission, 2004). Published in 2004, and built upon the *Science Content Standards* adopted in 1998, this document (1) expresses a vision for science learning that focuses on foundational facts and knowledge, and (2) has shaped science learning in California since that time by setting out these standards and guiding the most recent (2006) state adoption of materials. Unlike the California frameworks for English language arts and mathematics that explicitly advocate a particular number of uninterrupted instructional minutes in each of those subjects, the science framework does not. In fact, it acknowledges that science is a lesser priority, often eliminated because of the demands of English language arts and mathematics. The science framework suggests ways to fit science in by integrating it with other subjects and fitting it in to whatever time is available.

The priority of science is also minimized within California accountability systems. California's Academic Performance Index for elementary schools is a calculated composite that barely acknowledges science test scores: English language arts test scores are weighted 56.9%; mathematics scores, 37.6%; and science scores, 5.9%. Similarly, the achievement of federal Adequate Yearly Progress (AYP) targets is based almost entirely on English language arts and mathematics test scores. The results of the AYP are used to identify schools and districts for interventions. At the school level, these interventions may include termination of the principal or replacing existing staff. At the district level, the intervention typically entails the assignment of a District Assistance and Intervention Team. These teams follow guidelines adopted by the State Board of Education that emphasize performance in English language arts and mathematics.

California's infrastructure for supporting science education has eroded over the past 10 years. It used to be typical for county offices of education to have science coordinators and for district offices to have science coordinators and/or coaches. Today, these support providers are scarce. Statewide programs and resources have also been hit hard. In 2001 the California Science Project (CSP), offering teacher and teacher leader professional development across the state, was funded at $4 million. In 2002–03, CSP funding increased to a total of $9.09 million, $4.84 million of which were state funds. Today, CSP has minimal funding—$1.2 million in 2011 comprised of both state and federal funds. Further, the instructional materials adoption process that, in the past, occurred every 7 years and offered opportunities to refresh the curricular options available to teachers has been suspended for several years.

A Blueprint for Great Schools, prepared for California State Superintendent of Public Instruction Tom Torlakson, outlines many crucial recommendations for changing the system, including teacher preparation and materials adoption (Transition Advisory Team, 2010). Although such reform could support the improvement of science education, explicit attention will be required to ensure that this blueprint is applied to science learning in ways that increase the quality and quantity of science learning in California schools. Further, California will need a new road map for supporting science learning in public schools that aligns with national priorities for science education summarized in the section that follows.

The Imperative: Starting Early

To strengthen our system of science education, we must establish a strong foundation in students early. Although some have argued that young children are not ready to learn “real” science, the consensus among cognitive scientists is as follows:

> All young children have the intellectual capability to learn science. Even when they enter school, young children have rich knowledge of the natural world, demonstrate causal reasoning, and are able to discriminate between reliable and unreliable sources of knowledge. In other words, children come to school with the cognitive capacity to engage in serious ways with the enterprise of science (NRC, 2007).

Again, California citizens hold beliefs consistent with expert opinion. As far as Californians are concerned, the earlier students are introduced to science the better. A full 7 in 10 say that learning science should begin in elementary school in order for students to succeed in high school (Belden et al., 2010).

Along with this consensus about the need for students to learn science, similar agreement has evolved about how and what students should learn. In 2006, the National Research Council’s (NRC’s) Board on Science Education convened a panel of experts to synthesize relevant research and make recommendations for the future of science learning opportunities in schools that are documented in *Taking Science to School* (NRC, 2007). *Ready, Set, Science* (Michaels, Shouse, & Schweingruber, 2007) provides an educator-friendly summary of the panel’s findings; high-quality science education must include opportunities for K–8 students to do the following:

- Learn about what scientists really do
- Learn and use the language of science
- Reason scientifically (e.g., engage in causal and mechanistic explanations of natural and physical phenomena, provide explanations based on evidence)
- Engage in the practices of science
- Build on prior knowledge, interest, and experience
- Learn core concepts related to big ideas in science (e.g., atomic-molecular theory of matter, evolutionary theory, cell theory) presented according to an understanding about the way children learn and build knowledge about these concepts.

This work has been succeeded by additional science learning consensus documents. The most recent, *A Framework for K–12 Science Education* (NRC, 2011), cites the inadequacy of U.S. science education as the rationale for developing a new framework and emphasizes science as both ideas and practices.

> The overarching goal of our framework for K–12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (NRC, 2011; Executive Summary, p. 1)

This framework is the basis for the new generation of national common standards for science education currently under development. California has been chosen as one of 20 states to lead a nationwide effort to develop the next generation of science standards. As a lead state partner, California will help guide the standards writing process, gather and deliver feedback from state-level committees, and work with other state partners to address common issues and challenges. Once the final set of standards is complete, states may voluntarily adopt it to guide science education in their schools.

The Need: Timely and Actionable Data

Within this context, this study was conducted in support of *Strengthening Science Education in California*, a research, policy and communications initiative. Partners in this initiative include the Center for the Future of Teaching and Learning at WestEd; the Lawrence Hall of Science at the University of California, Berkeley; SRI International; Belden Russonello & Stewart; Stone's Throw Communications; and Inverness Research. The research conducted as part of this initiative was designed to provide data on the status of science education in California and identify how science education (with special attention to science in elementary school) can be strengthened. Our objective is to portray accurately the state of science education in California and to describe cases where schools have succeeded in providing students with productive and meaningful opportunities to learn science. The ultimate goal of this work is to inform policymakers and practitioners in their efforts to strengthen science education in California.

This initiative began with a public opinion survey, resulting in the 2010 report *A Priority for California's Future: Science for Students* (Belden et al., 2010), which underscored that Californians believe science education is vital to the future of the state and want science education to be a priority for our schools. During 2010–11, we undertook a series of data collection activities including surveys of district administrators related to K–12 science education, elementary and middle school principals, and elementary and middle school teachers; case studies of elementary schools; and data available through existing statewide datasets.

This report responds to the need for timely and actionable data on the status of science education in California's elementary schools and describes the status of science education in California public elementary schools.[1] It draws on the following data sources:[2]

- **A survey of district administrators.** We selected a stratified random sample of 451 districts across the state from the full list of California unified, elementary, and high school districts. In each district, we asked the individual primarily responsible for science education to respond to a series of questions about district policies and practices. This report draws on responses related to elementary schools. Response rate: 62%.
- **A survey of elementary school principals.** We selected a fully random sample of 300 elementary schools in the state and surveyed the school principal about science education policies and practices. Response rate: 56%.
- **A survey of elementary school teachers.** In each of the 300 elementary schools in the principal survey, we selected up to five teachers (depending on school size) at random for a total of 775 teachers and asked them to complete a survey on their teaching of science, their preparation, and the support they receive. Response rate: 70%.

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[1] Findings on secondary education will be available on the Center for the Future of Teaching and Learning website at www.cftl.org and in future reports.

[2] All differences among groups of survey respondents (e.g., principals in low-poverty schools compared with principals in high-poverty schools) highlighted in this report are significant at a p value of .05 unless otherwise noted. Additional information on our methodology is included in the Appendix. Supplemental statistical information can be found at http//www.cftl.org/Our_Publications.htm.

- **Case studies of promising elementary school efforts to teach science across the elementary grades.** The research team conducted an extensive nomination process to identify elementary schools that serve typical California student populations and are engaging in promising efforts to provide science learning opportunities across the elementary grades. In addition, we conducted Internet searches and an analysis of fifth-grade science CST scores to nominate additional elementary schools. In the end, we had a total of 46 nominated schools and districts. After eliminating nominated schools with fewer than 50% of their students proficient or advanced on the fifth-grade CST, the research team called the remaining nominated sites to verify that they had efforts in place to teach science across the elementary grades and, if they did, to invite them to participate. Nine schools met the nomination criteria and agreed to participate.

Chapter 2 describes the student experience in California classrooms and the quality and quantity of elementary science learning opportunities. Then we discuss the conditions that support and constrain quality and quantity. In Chapter 3, we examine elementary teachers' preparation and professional development experiences and how they address the challenges associated with providing high-quality science education. We also describe the curricular and instructional materials available for classroom use and local assessment practices. In Chapter 4, we consider leadership and resources available to support science education in California public elementary schools. Chapter 5 concludes the report with future considerations.

CHAPTER 2
SCIENCE LEARNING IN CALIFORNIA CLASSROOMS

"Today, we'll do a science experiment with a partner. We have to do it carefully or it will get very messy. We'll focus on observing. How do scientists observe?" the teacher asks. Students respond, "Use your senses," "Look at it," "Examine it."

Then the teacher asks one student per small group of two to three students to come up and get a bottle filled with water.

"What do you notice about the bottles?" the teacher asks. A student responds, "There are bubbles; it's cold."

"Where do you think the bubbles are coming from?" the teacher continues. The student replies, "Carbonation, or it might be salt." The teacher offers, "It's not a fizzy bottle. Come get another bottle. Does it look the same?" Another students says, "It's less bubbly; the bubbles are only at the top." The teacher then walks around and fills the bottles up to the top. She explains, "I'm going to come around and put red food coloring in the first bottle and blue in the second one." Once the teacher finishes putting in the food coloring, students share what they observed about the food coloring. One says, "It floats more on the salt water [red] and mixes into the fresh [blue]." The teacher then instructs them to gently turn the bottle over with their palm on top and mix the color evenly in each bottle.

Next, the teacher assigns the groups as either "fresh cats" or "salty dogs." Then she holds up a worksheet and explains, "Scientists always predict, so first you'll make predictions. Draw what you think will happen when you put one bottle on top of the other." Students take a few minutes to draw their predictions about what will happen to the water. Next, the teacher shows the students how to invert one of the bottles so that they can put it on top of the other. The students follow suit, putting one of the bottles on top of the other. It's quite a challenge not to spill water in the process. The fresh cats put the bottle with fresh water on top and notice that it does not mix in with the water in the bottom bottle. However, when the salty dogs put the bottle of salt water on top, it mixes in with the blue water in the bottom bottle and the water turns purple.

The teacher walks around the room and checks in with each of the student groups. She asks them open-ended questions, providing them an opportunity to explain what they observed without evaluating their explanations as right or wrong.

About 45 minutes into the lesson, the teacher brings the class back together and calls on students to explain what they saw in each of the experiments. They mostly comment on observing that the salt water mixed in when it was on top. Next, the teacher does a demonstration in front of the class, turning the bottles sideways so the blue water ends up on top.

> The teacher then asks, "When we put fresh water on top of salt water what happened?" A student responds, "There was a tiny bit of mixing." Drawing on what she learned in previous lessons, another student says, "It turned into an estuary." The teacher probes, "What do you mean by that?" The student says explains, "It was salty and fresh."
>
> The teacher then asks, "Why do you think that happens?" and another student explains, "The salt water was heavier; it went to the bottom."
>
> The teacher then extends the conversation further. "What happens when the tide comes in?" she asks. A student answers, "It turns into an estuary —it's mixing."
>
> "What's the science word for water moving or mixing?" the teacher asks.
>
> "Currents," students reply.
>
> The teacher then draws on the board a diagram of the mixing of the currents in an estuary and explains that the current makes wetlands rich by mixing in oxygen so plankton can thrive. She then explains that salt water is denser than fresh water—it is heavier—and recaps what they did in the lesson: "We created a mini-current in our bottles." Finally, she lets them know of other ways to make currents: "Wind can make a current; gravity in a river makes a current. Hot and cold water can also make a current."
>
> Fifty-five minutes after beginning the lesson, the teacher instructs students to clean up and put away the materials. Students take their bottles to the sink and empty them.

Children rarely encounter high-quality science learning opportunities in California elementary schools because the conditions that would support them are rarely in place.

This lesson occurred in one of our case study sites and is an example of the type of hands-on inquiry-based science lesson envisioned in the emerging consensus on the features of high-quality science learning opportunities discussed in Chapter 1 (see also NRC, 2007, 2011). This type of lesson offers elementary school students the opportunity to build on their own ideas, to engage in investigation and collaboration with other investigators and other practices of science (e.g., modeling, exploring and observing scientific phenomena, constructing explanations based on evidence), to reason scientifically, to learn and use the language of science, and to learn core concepts related to big ideas in science.

Unfortunately, far too few children have the opportunity to engage in lessons like these in California elementary schools. Moreover, because of the limited time spent on science in California classrooms, elementary school students receive little exposure to the "science as foundational facts and concepts" vision of science education embodied in the California state standards, adopted instructional materials, and assessments. In fact, children rarely encounter high-quality science learning opportunities in California elementary schools because the conditions that would support them are rarely in place.

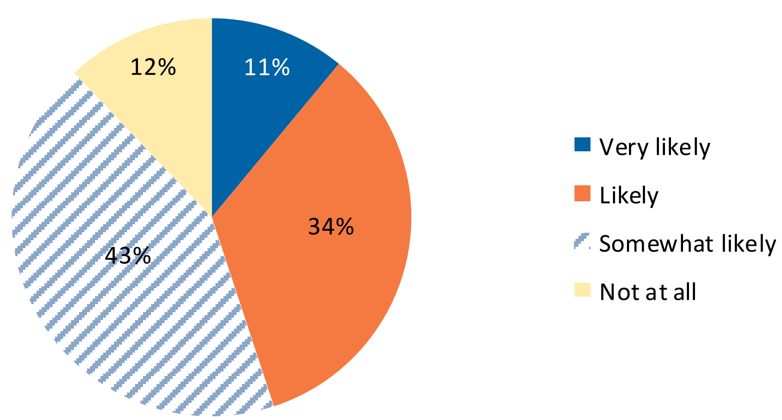
In this chapter, we describe elementary students' learning opportunities in California classrooms. We begin with the quality of science learning that students experience and then consider the restricted time available for science instruction in elementary schools.

The Nature of Students' Science Learning Opportunities

> ***Few children have the opportunity to engage in high-quality science learning experiences in elementary schools.***

Few elementary students are ensured of high-quality opportunities to learn science, and elementary school principals are the first to admit this. Only 11% of principals surveyed indicated that it was very likely that a student would receive high-quality science instruction in his/her school; an additional 34% said that students were likely to receive such instruction. Twelve percent of principals reported that it was not at all likely that students would receive high-quality instruction. (Exhibit 2-1).

Exhibit 2-1
Elementary School Principals' Reporting of the Likelihood That Students Receive High-Quality Science Instruction



Source: 2011 Statewide Science Education Survey of Elementary School Principals.

For a more in-depth perspective on the types of learning opportunities available in the classroom, we asked elementary school teachers about their specific instructional practices (Exhibit 2.2). None of these practices alone indicate whether high- or low-quality science learning is taking place in a particular classroom. Rather, some represent instructional approaches (e.g., reading a textbook or watching a demonstration) that tend to foster the **development of foundational facts and knowledge**.

Other activities provide opportunities for students to actively engage in their learning of core scientific concepts by asking investigable questions, building on their knowledge, designing their own investigations, and analyzing and interpreting their own data. These activities are aligned with the NRC (2007, 2011) vision that students need opportunities to **engage in the practices of science** in order to learn both the ideas and practices of sciences.

A final set of practices of interest reported here **support English language learning** through science because of the increasing number of teachers, schools, districts, and curricular materials pursuing such opportunities. Integration of science with other subject areas is suggested in the *Science Framework for California Schools* (Curriculum Development and Supplemental Materials Commission, 2004). Although increasingly common, this strategy is not yet widespread—32% of elementary school teachers surveyed reported doing integrated activities always or often. The most typical of these practices is integration of science with English language arts (ELA) or English language development (ELD) time.

We recognize that some of the instructional practices fall into more than one of these three groups depending on their implementation; for the purposes of presenting descriptive results in Exhibit 2.2, we display each only once within one category consistent with typical implementation.

Exhibit 2-2
Frequency of Use of Instructional Practices in Science in Elementary School Classrooms (Percentage)

Practices that provide opportunities to:	Always/Often	Sometimes	Rarely	Never
Learn foundational facts and knowledge				
Read textbook	48%	34%	10%	8%
Watch demonstration	36	54	8	2
Take notes and listen	33	33	14	20
Answer textbook or worksheet questions	32	47	13	7
Watch audio-video presentations	30	53	13	4
Engage in the practice of science				
Work in groups	65%	30%	4%	1%
Do hands-on activities	42	40	16	2
Record or analyze data	29	49	17	5
Design their own investigations	7	31	38	25
Do fieldwork	3	18	30	49
Support English language learning				
Read non-textbook materials	30%	51%	16%	3%
Write reflections	24	42	24	11
Present to the class	10	38	32	21
Write reports	6	30	36	28

Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Among the instructional practices often associated with efforts to build foundational facts and knowledge, the one reported to be most frequently used was reading textbooks (48% always/often). The other activities (watching a demonstration, taking notes/listening, answering textbook or worksheet questions, and watching audio-video presentations) took place in about a third of California elementary classrooms on a regular basis.

When science is taught, of the instructional practices often associated with efforts to engage students in the practices of science, working in groups (65% always/often) and doing hands-on activities (42% always/often) were those most frequently used by elementary school teachers in California. Other activities in this cluster that require greater initiation and action on students' part, such as designing their own investigations and doing fieldwork, were used infrequently. These, of course, are the kinds of activities that scientists undertake in their daily work.

Regarding instructional practices that support English language learning using science content, students in less than a third (30%) of elementary classrooms read non-textbook materials (e.g., tradebooks) related to science and about a quarter (24%) write reflections about their science learning. More striking, only 10% of elementary school teachers ask students to "present to the class," and only 6% have students write reports on a regular basis.

As noted, implementation of any of these practices can vary widely. For example, students can be asked to tackle hands-on tasks that do not engage their minds in real scientific work. They might record data by copying it from a blackboard or textbook rather than through their own experimentation or fieldwork. On the other hand, students can work in groups to fill out worksheets that are designed to support them in making sense of scientific concepts and phenomena. Similarly, students can read a text or watch a presentation as the background for initiating their own investigation.

Approximately 10% of elementary students in California experience a pattern of classroom practices that supports regular engagement in the practices of science.

Across all teachers in our sample, we estimate approximately 10% of elementary students in California experience a pattern of classroom practices that supports regular engagement in the practices of science. This pattern of practices includes regular student engagement in all the following: work in groups; do hands-on or lab science activities or investigations; design or implement own investigation; participate in fieldwork; record, represent, or analyze data; write reflections; present to the class; and write reports. Analyses of the characteristics of elementary teachers who engaged in this pattern indicated that they offered more minutes of science instruction, felt better prepared to teach science, and were slightly more likely to use Full Option Science System (FOSS) materials than any other adopted curricula. Also, these teachers appear to be more likely to have received support through partnerships with organizations outside of their school districts than other teachers. Even though this difference in survey results regarding partnerships is not statistically significant, we report it because we found a similar trend in the analysis of the case study data.

Despite the challenges, some elementary school students have the opportunity to engage in the practices of science.

Some elementary school teachers provide students with opportunities to work as real scientists. As one elementary school teacher in a case study school explained as follows:

> If you really want to get somebody fired up about something like science, they have to actually work the way a scientist would work. They can't just be a passive observer of science. They have to become a scientist. They have to engage in investigations and experiments.

Another elementary teacher shared her perspective on supporting students to understand the nature of working as a scientist.

> Scientists often learn from their mistakes. We had that happen when we melted our agar plates because the temperature was turned up too high.

> So they learned about the scientific process—it's not always an experiment that works; sometimes our observations are wrong or experiments go wrong. But that doesn't mean we quit, we try again. It's really a good skill for kinder[garteners] to be able to say they made a mistake, and that's OK we'll try again. What should we do different this time? So reinforcing this in science is great.

Strong science activities in elementary classrooms take many forms.

Strong science activities in elementary classrooms take many forms. The example that opened this chapter was a rich hands-on science lesson that actually supported students in engaging in investigation, experimentation, and scientific reasoning. In another case study elementary school, the science teacher emphasizes hands-on experiences that invite students to identify with the environment surrounding the school while learning science skills and making discoveries about the natural world. An important aspect of these experiences is that they often take place in the classroom and in the field and build on students' prior experiences and knowledge. For example before a water monitoring lesson at the local lagoon, students reflected on prior water monitoring lessons and shared their hypotheses about how the findings from that day's activity might be similar or different from findings from the start of the school year. During the debriefing discussion, students were asked to report on their findings and compare them with their hypotheses. They also were asked to develop a new hypothesis about why the readings from the fall and winter data collections were different.

Providing opportunities for students to design and implement their own investigations appears to be especially challenging.

Providing opportunities for students to design and implement their own investigations appears to be especially challenging, but it is exactly what science involves. An elementary school teacher in one of our case study schools described what providing such opportunities entails:

> They develop their own investigations...It's usually about once every 2 months. They come to me with a proposal...I do have books of science activities that they can look at if they can't think of anything they'd like to do. There are suggestions, of course…they're always related to what we're studying…They usually have about 2 weeks, and then they demonstrate the activity to the class and show their results…they put together a poster that would be on display in the hallway.

This example brings together a number of characteristics of high-quality science teaching. The teacher brings materials and focus, but the students make active choices. The teacher establishes the structure and the timeline, but the students actually carry out the investigation. Results are not just gathered—they are analyzed, written up, and then communicated to peers. Finally the results are published.

Time for Science Learning and Teaching

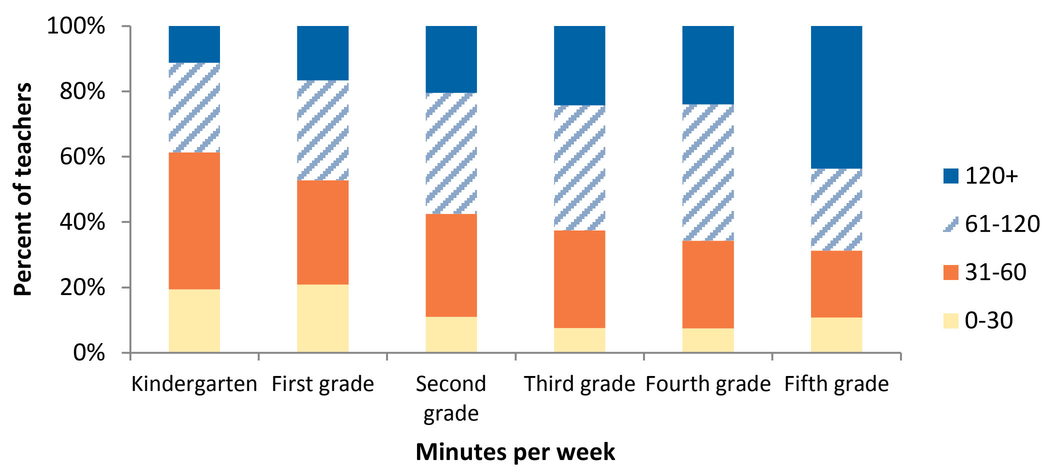
Limited time is devoted to science learning in California elementary schools.

If students are to learn science, they need time to do so.

If students are to learn science, they need time to do so, and very little time is devoted to the teaching of elementary science in California classrooms. There is no set "right amount" of time for science. California does not require a minimum number of minutes for science instruction, although some districts and other states do. Oakland, for example, requires a minimum of 60 minutes per week in grades K–3 and 90 minutes in grades 4–5. New York City calls for 135 minutes weekly in K–2 and 180 minutes in Grades 3–5. Arizona suggests 150 minutes in grades 1–2 and 200 minutes in grades 4–6. Some publishers of California-approved science instructional materials offer guidance on the appropriate amount of instructional minutes with one suggesting 90–135 minutes a week, and another a minimum of 135 minutes per week.

Exhibit 2-3 summarizes the amount of time elementary school teachers spent on science instruction in a typical week in California. In K–1, more than half the teachers spent less than an hour per week on science. As a student moves up the grades the amount of time allocated to science increases, especially in fifth grade where science is tested. Yet, even at fifth grade most students had less than 120 minutes of science instruction per week.

Exhibit 2-3
Time Spent on Science Instruction in Elementary School



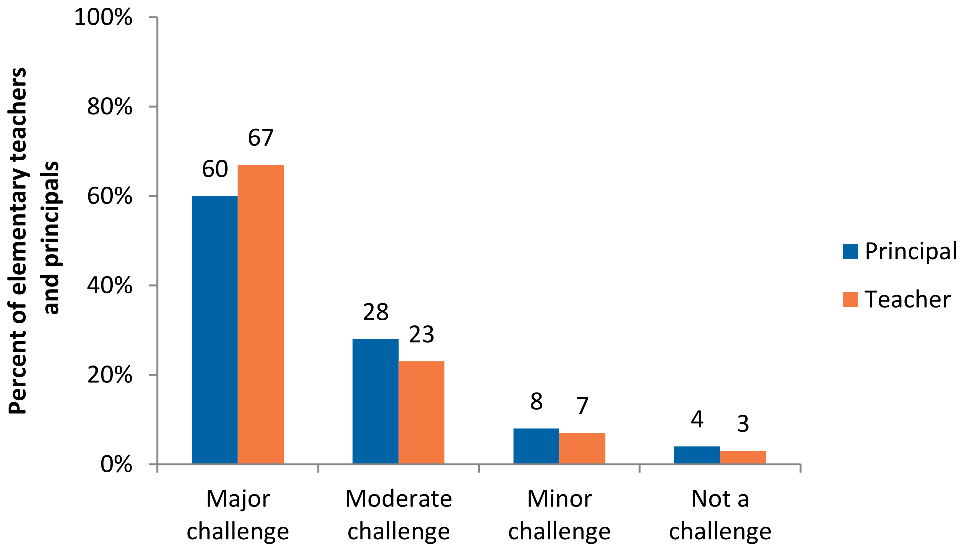
Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Disturbingly, looking across all grade levels, 40% of elementary teachers reported that their students received 60 minutes or less of science instruction per week; indeed, 13% of elementary teachers reported that their students received 30 minutes or less.

Elementary school teachers and principals agreed that not enough time is dedicated to science learning. In fact, among the multiple challenges to providing science instruction, both groups saw limited time as the most significant. Two-thirds of elementary teachers saw time as a major challenge to providing science instruction while an additional quarter of teachers viewed it as a moderate challenge. Elementary school principals' responses were similar (Exhibit 2-4).

Elementary school teachers and principals agreed that not enough time is dedicated to science learning.

Exhibit 2-4
Elementary School Teachers and Principals Reporting Limited Time for Science Education as a Challenge



Source: 2011 Statewide Science Education Surveys of Elementary School Teachers and School Principals.

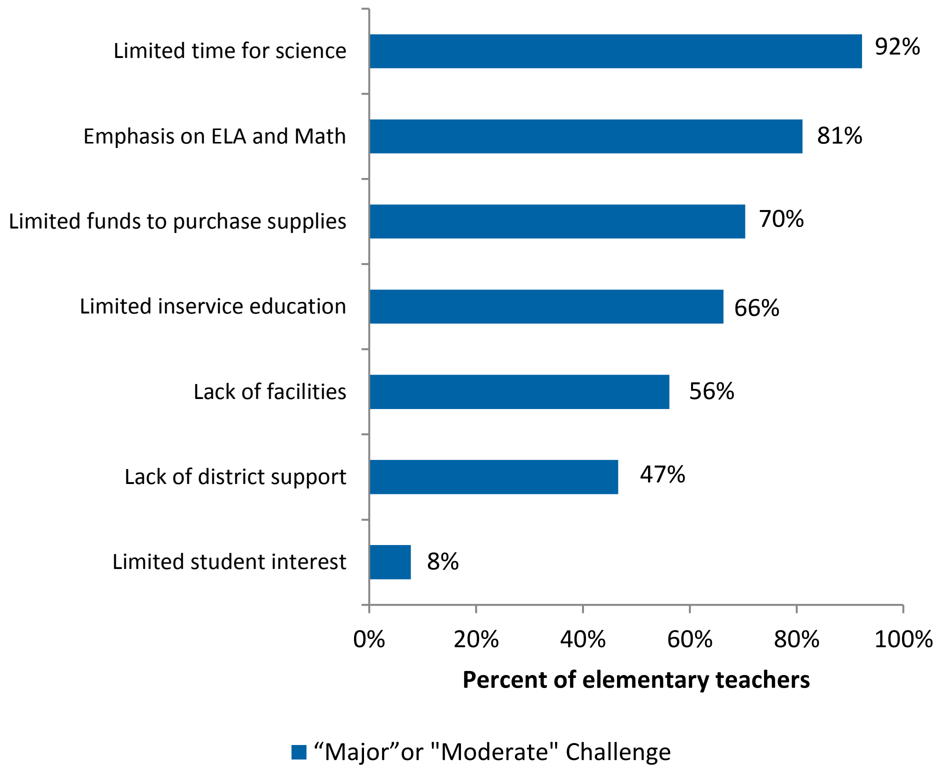
Accountability pressures related to English language arts and mathematics explain in part the lack of time for elementary science.

Schools are under pressure to meet both federal and state achievement targets—and those targets are weighted heavily toward English language arts and mathematics in elementary schools. Several teachers surveyed and interviewed indicated that they want to teach science, but they have no time. As one elementary teacher noted:

> I love teaching science, and my students enjoy learning it. There's just so much else we have to cover (English language arts, mathematics, ELD). It's hard to get science in.

Elementary teachers consistently point to "time" and "the focus on English language arts and mathematics" as the greatest challenges (Exhibit 2-5).

Exhibit 2-5
Elementary School Teachers Reporting Major or Moderate Challenges



Source: 2011 Statewide Science Education Surveys of Elementary School Teachers

Given the influence of accountability measures and the findings of previous research (Dorph et al., 2007), we expected the pressure to concentrate on identified for Program Improvement (PI) for not meeting accountability benchmarks. Individual teachers in these schools did underscore the pressures they felt. One teacher recounted, "I was told that I could not teach science because the school is in year 4 of Program Improvement," while another reported, "We are a PI school and it is not in our schedule given to us by the district."

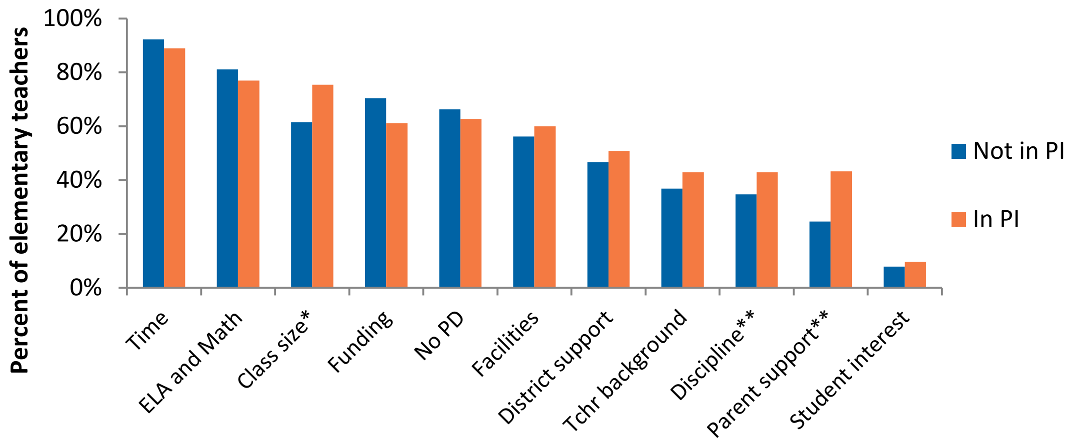
Even in non-Program Improvement schools, teachers used words like "sneak" to describe how they were able to find time to teach science.

But it would be a mistake to think that just teachers in Program Improvement schools face this pressure. Even in non-Program Improvement elementary schools, teachers used words like "sneak" to describe how they were able to find time to teach science. As one elementary school teacher noted, "I would love to be allowed to freely teach science and schedule it in the pacing guide. Now I have to sneak it in and close the door. The district needs education on the importance of science!" High-performing elementary schools are not necessarily immune from the push for English language arts and mathematics education. Another elementary teacher noted, "Even though our students outperform their peers on state tests, our district overemphasizes reading."

The statewide survey responses were consistent across Program Improvement elementary schools and other schools, with few significant differences. When asked about their greatest challenge, elementary teachers in both Program Improvement and other schools named time and the focus on English language arts and mathematics, with no statistical differences (Exhibit 2-6). In short, everyone is under pressure to focus on English language arts and mathematics; this focus limits the amount of time available for science and other subjects in elementary schools.

Everyone is under pressure to focus on English language arts and mathematics; this focus limits the amount of time available for science and other subjects in elementary.

Exhibit 2-6
Elementary School Teachers Reporting Major or Moderate Challenges, by School-Level PI Status



* Significant differences between PI and non-PI schools at *p* =.05.
** Significant differences between PI and non-PI schools at *p* = .01.
Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Some teachers, schools, and districts increase time for science learning in elementary schools by integrating science with other content areas.

The *Science Framework for California Schools* (Curriculum Development and Supplemental Materials Commission, 2004) explains that integration of science with other subject areas can support the curricular efficiency necessary to accommodate science given the minutes spent on English language arts and mathematics as directed by the state frameworks. In line with this suggestion, a number of teachers, schools, and districts integrate science with other subjects at the elementary school level. As mentioned, 32% of elementary school teachers surveyed reported doing integrated activities always or often, the most typical being integration of science with English language arts or English language development time.

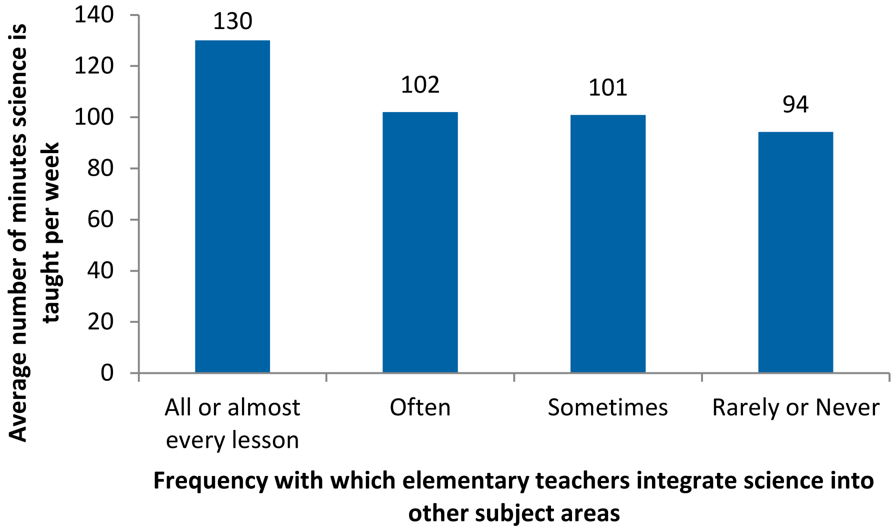
Some teachers and districts have embraced this strategy as an opportunity to support both science and English language learning in elementary schools, recognizing the synergies it offers.[3] For instance, one school we visited used science content to teach English language arts through its science literacy class. As the former principal explained, an "essential belief was that science as a content area…was also a wonderful vehicle for the teaching of ELA essential standards." The content of the science literacy classes was tied to that of the science lab classes so that they reinforced each other. Other elementary teachers' descriptions indicated that integrating science with English language arts can mean very different things at different schools. For some, it simply means that some of the books students read during English language arts time are nonfiction science texts. For others, the implementation of integration is far deeper, offering integrated opportunities for vocabulary development in science and nonscience, reading, writing, and speaking as well.

Elementary school teachers discussed three main benefits to integrating science and other subjects. First, students realize that science permeates everything—they begin to see science in their everyday lives.

Elementary school teachers discussed three main benefits to integrating science and other subjects. First, students realize that science permeates everything—they begin to see science in their everyday lives. As one elementary school teacher said, "I think it's important that kids know science isn't just during science lab; we're scientists all the time. Predicting, questioning, all those skills are done almost every second of the day." Second, because science content is interesting, students are more likely to read and comprehend; this strengthens their language arts skills. Reading about science also provides experience with expository writing, a frequent component of the state testing system. Third, integrating the subjects allows more time for each, especially science. Elementary school teachers who indicated on the survey that they integrated science with other subjects in all lessons or almost every lesson offered science an average of 130 minutes a week, compared with an average of 94 minutes per week for teachers who rarely or never integrated science with other subjects (Exhibit 2-7).

[3] An increasing body of research provides evidence for the efficacy of deep integration of science and English language arts as well as for increasing numbers of instructional materials and professional development opportunities in line with this strategy.

Exhibit 2-7
Duration of Science Instruction When Elementary School Teacher Integrated Science with Other Subject Areas



Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Integrating science with English language arts and/or English language development is not simple. Districts, schools, and teachers require significant support (professional development, appropriate instructional materials, etc.) to implement this strategy well and allow it to realize its potential learning benefits. Several California organizations currently provide support and develop instructional materials for those seeking to integrate science with English language learning.

Summary

This chapter paints a portrait of science teaching and learning in California's elementary schools that draws on statewide surveys of principals and teachers as well as in-depth case studies of selected elementary schools. The results are sobering if not entirely surprising. Science takes a backseat to English language arts and mathematics, the subjects that count most in federal and state accountability systems. Across the state, students receive fewer minutes of science instruction than is generally recommended.

The science learning opportunities that most students receive fall short of what the emerging national consensus calls for: more active, student-initiated, real-world-based investigations. The vision of such instruction is that students have the opportunity to engage in the practices of science and thus come to understand the true nature of science. A handful of elementary teachers throughout California are, however, going far to realize this vision, and we have offered a glimpse into their classrooms.

In the next chapter, we discuss the conditions for science education—the teacher workforce, materials, and assessments that shape the nature of science teaching in California and account in part for what happens in classrooms.

CHAPTER 3
THE CONDITIONS THAT SHAPE SCIENCE LEARNING OPPORTUNITIES

In Chapter 2, we saw that most elementary school students rarely have opportunities to engage in learning experiences where they generate their own questions and seek their own solutions to scientific problems. In this chapter, we turn to the conditions for science education in California, addressing arguably the three most important factors influencing the quality of science learning opportunities: teachers, materials and facilities, and assessments.

Few elementary teachers have strong science backgrounds and the support they receive once they enter the profession is minimal.

We begin with teachers because they are a critical determinant of what goes on in a classroom. We discuss how prepared teachers are to teach science and the professional development and other supports they receive to help them do so. We found that few elementary teachers have strong science backgrounds and the support they receive once they enter the profession is minimal.

We turn next to instructional materials (including curriculum) and facilities. These are of particular importance in science because much of science requires consumable materials, scientific tools, and special facilities to enable students to investigate natural phenomena. We discuss which curricular materials are adopted, used, and supported in the state's classrooms. We find that for a variety of reasons, some of them logistical, California elementary school teachers have limited access to the high-quality curriculum and instructional materials that they want. They also lack specialized tools and facilities.

Children rarely encounter high-quality science learning opportunities in California elementary schools because the conditions that would support them are rarely in place.

Finally, we discuss the challenge of assessment. In a state where science is tested only once during the elementary school years (toward the end of fifth grade), how are teachers, principals, and district administrators to track their students' progress in science? In general, we find there are no local science assessment systems in place that enable educators to track the progress of student learning in science across classrooms in the elementary grades or to modify science instruction.

Overall, the findings from this chapter reinforce the report's overall conclusion that children rarely encounter high-quality science learning opportunities in California elementary schools because the conditions that would support them are rarely in place.

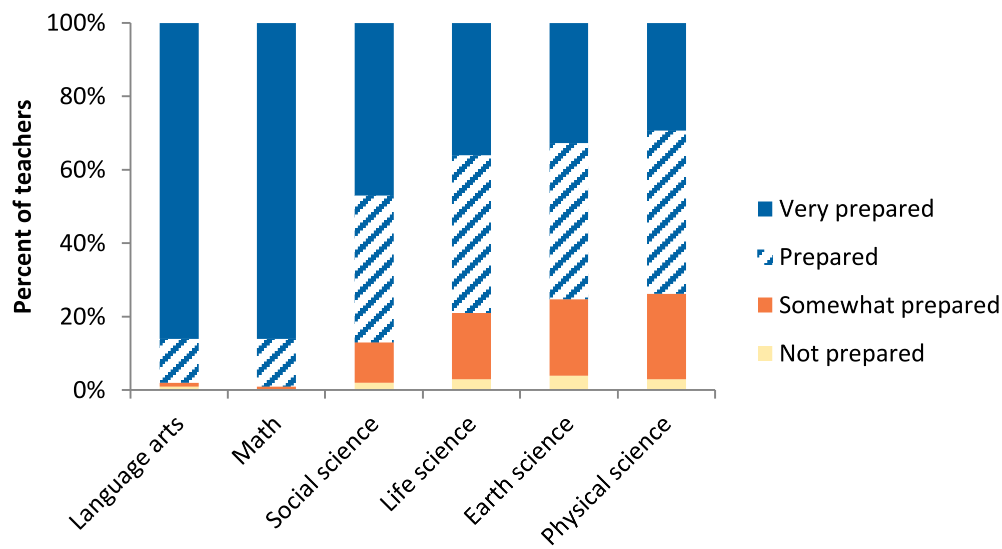
Teacher Preparedness to Teach Science

Elementary school teachers feel less prepared to teach science than other subjects; they feel least prepared to teach physical science.

Most elementary school teachers felt substantially less prepared to teach science than other subjects.

Elementary school teachers rarely have an undergraduate or graduate major, minor, or concentration in science disciplines. According to the California Commission on Teacher Credentialing, only 1.4% of all individuals who hold an elementary school credential (multiple-subject credential) have a bachelor's or master's degree in science (Marjorie Suckow, California Commission on Teacher Credentialing, personal communication, June 10, 2011).[4] As part of this study, we asked teachers about their perceptions of their own level of preparation to teach science. Most elementary school teachers felt substantially less prepared to teach science than English language arts and mathematics (Exhibit 3-1). Although almost 90% of teachers felt very prepared to teach English language arts and mathematics, only about one-third felt very prepared to teach science. They were more likely to feel prepared to teach life science than either earth/space or physical science.

Exhibit 3-1
Elementary School Teachers' Reported Preparedness to Teach Various Subjects

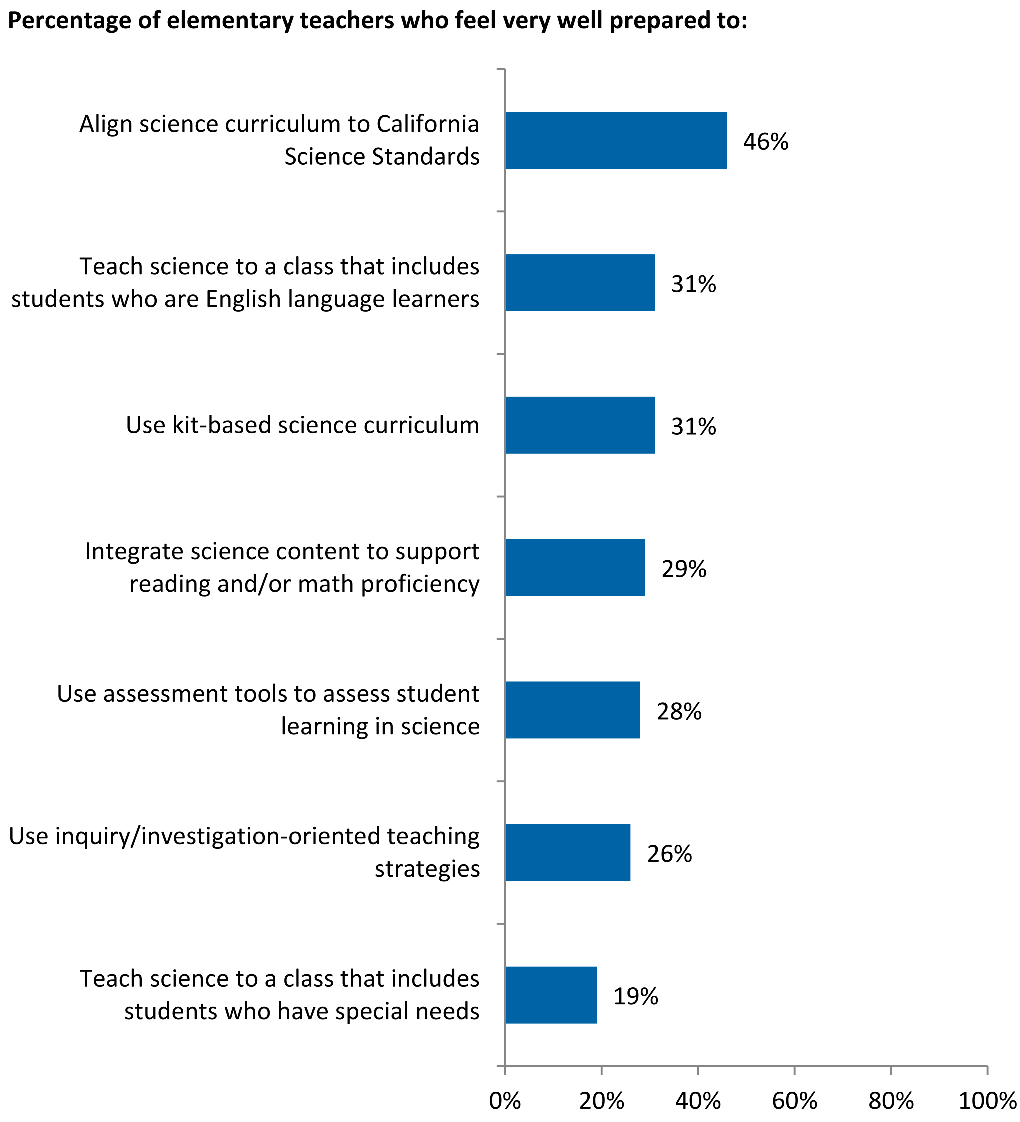


Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

4 For the purposes of this analysis, a degree in science was defined as one in biological science, chemistry, geosciences, or physics—the sciences more closely aligned with the content taught at the elementary school level.

We asked elementary school teachers to rate their preparedness to undertake specific activities within science instruction. Only between 20 and 30% described themselves as very prepared to engage in teaching practices expected of California elementary school teachers (Exhibit 3-2).

Exhibit 3-2
Elementary School Teachers' Reported Preparedness in Specific Science Instruction Activities



Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Even with a district infrastructure to support the implementation of a science program, the lack of teachers' science content knowledge continues to challenge the quality of instruction. As one elementary teacher said, "I feel that my own lack of science content knowledge is my biggest challenge."

Science Resource Teachers

Standing in the sunlit schoolyard, the second- and third-grade students prepare to use paper leaves to which they've attached light sensitive beads to explore the process of photosynthesis. With support from their teacher, pairs of students talk about and then act out the steps involve in the process. The teacher, Leslie, guides the group through each step in the process and circulates among the pairs, answering questions about how plants work. At the end of the activity, the students' hard work is rewarded as they share "glucose" (the key product of photosynthesis) in the form of jellybeans.

Science instruction at the school took a big step forward when Leslie joined the faculty directly out of her CSU teaching program 2 years ago. Leslie had worked as a soil scientist for over a decade before deciding to become a teacher. The school was thrilled to have a previously practicing scientist teach all the science lessons at the school. Using her scientific background, she was able to create an engaging science program in which students connect science to their lives, build on prior knowledge, share ideas, and actively engage in the practices of science.

The combination of Leslie's subject-matter knowledge and her pedagogic expertise allows her to make a difficult, abstract phenomenon tangible and comprehensible for all students in this K–8 school by making each component of the process visible.

Teaching Specialties

The fourth-grade teacher, Betsy, stands near the window of her classroom, arranging the science materials for the day: jars, paper lids, and mallow. While she works, she explains her plan for the upcoming lesson to the researcher—she will introduce the students to their "caterpillar friends" and help them anticipate the process of watching a caterpillar turn into a butterfly. She says, "I feel very confident with what I'm doing now, since I teach all science to all the fourth-grade students."

Two years ago, Betsy and her fellow elementary teachers decided to each "specialize" in certain subjects. Because she has always had an interest in science and has a daughter studying chemistry in college, Betsy volunteered to teach science; her two other fourth-grade colleagues specialize in social studies and art. Two times a week, they rotate students, for an hour each time, and teach their specialty subject to each other's students. They find this process helps keep them on track with the pacing guide and ensures that all students receive science, social studies, and art from a teacher who is prepared to teach it.

More importantly, each teacher seeks out professional development in her chosen subject area in order to deepen her content knowledge. This focus helps each build confidence, competence, and enthusiasm. As a result, she has noticed that her students are more enthusiastic about the material. Although there are some logistical issues, they have developed a system for keeping track of materials and providing feedback on each other's students. They feel that both they and the students benefit from this approach. The students, eagerly accepting responsibility for their "caterpillar friends," seem to agree.

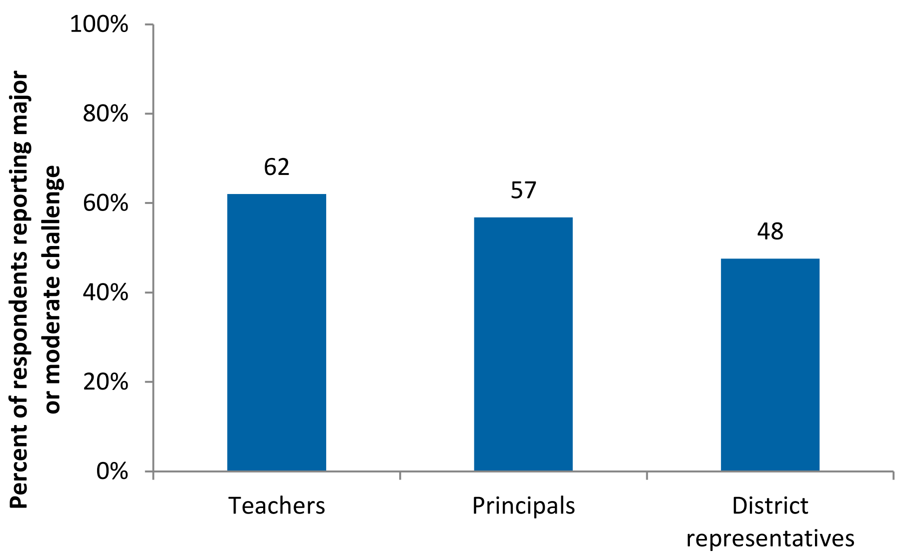
Professional development opportunities for elementary school teachers are scarce.

Over 85% of elementary teachers have not received any science-related professional development in the last 3 years.

Over 85% of elementary teachers have not received any science-related professional development in the last 3 years. Of the less than 15% who did, two thirds received 8 hours or less over the 3-year period; 59% of those who received professional development indicated that their district provided it. One third of those who received professional development reported that it was on the use of new instructional materials. As one teacher said, "The only training that has been offered was done by the publisher with the new textbook adoption."

Elementary teachers, principals, and district administrators all acknowledged that this lack of professional development is a challenge to providing science instruction in elementary schools (Exhibit 3-3).

Exhibit 3-3
Perception of Lack of Inservice Educational Opportunities as Major or Moderate Challenge



Source: 2011 Statewide Science Education Survey of Elementary School Teachers, Principals, and District Administrators.

Elementary school teachers have received little science-related training in the last 3 years for three reasons. First, professional development opportunities in general in California have been cut significantly over the past several years with the tightening of school budgets due to the state's economic crisis. An elementary teacher explained, "Earlier in my career, there was science kit training, but there has not been funding for that in the last few years." Second, remaining professional development opportunities are most likely tied to the curriculum adoption cycle. Because science curricula in most elementary schools have been in place for some years, several elementary teachers indicated that the trainings occurred as long as 5 years ago. One elementary teacher commented, “I haven’t had any since we adopted the curriculum a long time ago.” The third reason for the lack of science-related professional development, not surprisingly, is the emphasis on English language arts and mathematics. As one elementary teacher noted, “We do not get professional development in science. We are told it doesn’t matter in our AYP.”

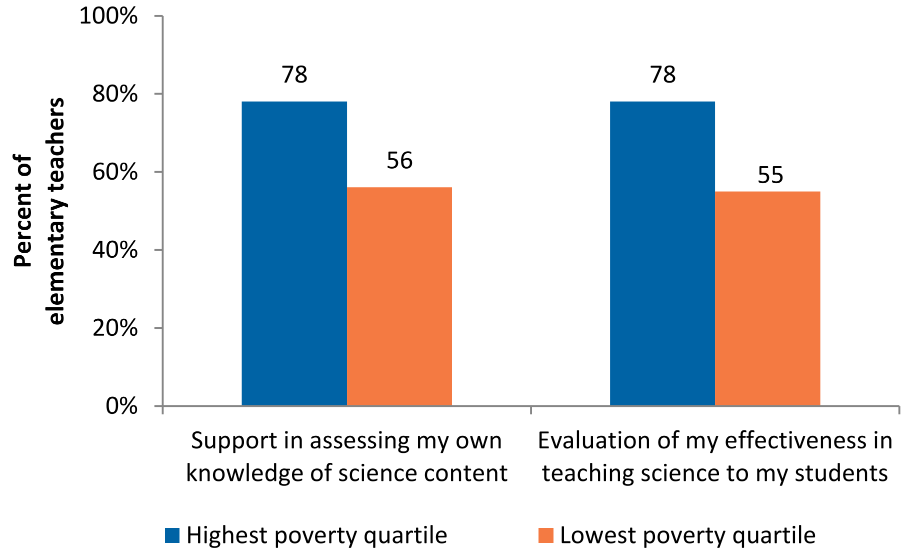
Asked to describe professional development that greatly affected their teaching, elementary teachers reported that sessions on the use of their classroom materials were helpful. As one teacher wrote in her survey, “Training for the… science kit on electricity and magnetism was impactful because I had not personally learned these skills in my education. It opened my eyes to the excitement of science and hands-on experiments.” In general, teachers thought these opportunities helped them understand how to incorporate the program and activities in their classroom.

One school we visited provided teachers with just this type of professional development by teaming with the California Science Project, FOSS trainers, and an expert in science literacy. Trainings included summer institutes and Saturday events to build teachers’ content and pedagogical content knowledge and provide time for teachers to put their new knowledge into practice by planning lessons together in grade-level teams. Presentations included training on earth, life, and physical sciences; materials management; and science literacy.

California elementary school teachers offered ideas about the types of professional development they would like to receive in science, including engaging students in hands-on or problem-based learning, using the science curricula or materials teachers have at their school, and building their science content knowledge. Principal surveys lead us to believe that such opportunities may be possible. Forty-eight percent of principals reported that they were planning to change how science is taught during the next 3 years, and 76% of those principals reported that they planned to add or increase the amount of professional development in science teachers receive.

In addition to the general lack of professional development opportunities, elementary school teachers pointed to specific areas where they received little or no support. Sixty-eight percent reported that they received little or no support at all in assessing their own level of science content knowledge or their effectiveness in teaching science. Teachers in elementary schools serving higher percentages of students in poverty were more likely to report receiving little or no support in these two areas than teachers in schools serving students with lower percentages of students in poverty (Exhibit 3-4). For example, almost 80% of elementary teachers (78%) in schools serving the highest percentages of students in poverty reported receiving little or no support for assessing their effectiveness in teaching science as compared with 55% of elementary teachers in schools serving the lowest percentages of students in poverty.

Exhibit 3-4
Elementary Teachers Who Receive Too Little or No Support at All, by School-Level Poverty Quartiles



Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Materials and Facilities to Teach Science

Elementary school teachers want their students to have materials that are engaging and hands-on. Some have them; some do not.

In 2006, California adopted a revised set of instructional materials for science. The adoption process ensured that those materials were aligned with California science content standards. District administrators reported that the most widely adopted materials are *California Science* (Macmillian/Mc-Graw Hill) and *California Science* (Pearson Scott Foresman) textbooks and *Full Option Science System (FOSS)-California Edition* (Delta Education)[5] on the current list of science materials adopted in California.

In their survey comments, several teachers express dissatisfaction with the materials they have available. One teacher explained she wanted "an easy to follow curriculum that is kid-friendly, teacher-friendly and allows for a lot of

[5] FOSS-California Edition is the only inquiry-based option on the current list of science materials adopted in California. By *inquiry-based*, we mean that the instructional materials are designed to lead students to construct an understanding of science concepts through investigations and analyses, using laboratory equipment, readings, and interactive technology.

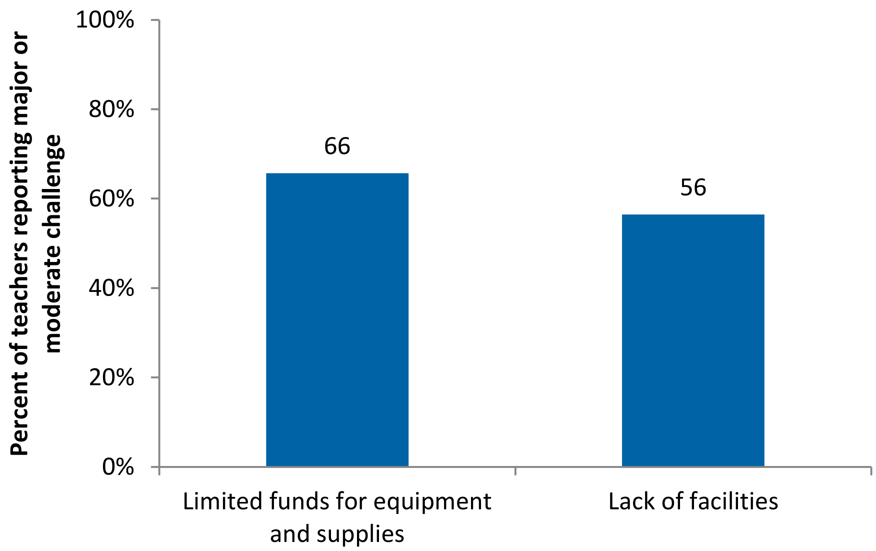
hands on experiences." In part because of the limitations of the materials, it is common for teachers to use supplementary materials. Thirty-seven percent of district administrators reported that teachers were using additional instructional materials to supplement their science instruction; 48% reported that the supplemental materials were primarily hands-on programs. We stress that the nature of the instructional materials does not guarantee any particular type of instruction. Using hands-on materials and science kits does not ensure that students actually have the opportunity to engage in the practices of science.

Elementary schools often lack the equipment and facilities to support hands-on, inquiry-based science for students.

In addition to having limited curricular options, many elementary classrooms suffer from limited space, facilities, and supplies for engaging in the practices of science. Seventy percent of elementary teachers reported having inadequate support for finding space for hands-on learning. In addition, elementary teachers reported that the limited of funds for equipment and supplies (66%) and lack of facilities (56%) presented a major or moderate challenge to providing science instruction (Exhibit 3-5). As one elementary teacher stated, "I'd love to have a science lab at our school so we could sign up for classes to rotate through, storing the kits there…It's hard to store all the materials, take things out, put things away, and have counter space for things to grow, animals to live."

Many elementary classrooms suffer from limited space, facilities, and supplies for engaging in the practices of science.

Exhibit 3-5
Elementary School Teachers Reporting Limited Funds and Lack of Facilities as a Major or Moderate Challenge to Providing Elementary Science Instruction



Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

Teachers in schools serving higher percentages of students in poverty were more likely to report that lack of facilities was a major challenge.

Unfortunately, teachers in schools serving higher percentages of students in poverty were more likely to report that lack of facilities was a major challenge to providing science instruction than teachers in more affluent schools. More than a third (35%) of elementary teachers in schools serving the highest percentages of students in poverty reported that facilities were a major challenge, compared with just 13% of teachers in the most affluent elementary schools.[6] Elementary teachers commented on the need to use their own money to purchase any additional supplies.

> Funding for the supplies we receive essentially comes out of our own pockets. It would be nice to know if there are grants out there for teachers.

> I go through the supplies very quickly. I also tend to use methods for teaching which are not necessarily straight from our science kits, so I purchase the materials myself.

Successful implementation of hands-on instructional materials can require additional infrastructure and personnel.

High-quality science learning opportunities that enable students to engage in the practices of science require the materials and tools of science. To make these materials and tools more easily accessible, many publishers package them into a kit that is available for purchase. Although these kits must be maintained and refurbished, this is far less burdensome than gathering or purchasing all the materials separately.

Still, for some elementary schools and classrooms, materials replenishment is an issue. Only half the elementary teachers who used kit-based programs are supported by a materials management system devised to replenish the kits. And about half (52%) of the teachers who use kit-based materials thought that materials replacement was at least somewhat of a barrier to teaching science.

It is critical for districts that expect teachers to use hands-on instructional materials to understand the infrastructure and resources necessary to ensure that these materials are available and used.

In a number of our case study sites, the districts had created centralized locations, sometimes called science material resource centers or science centers (see Exhibit 3-6), where kits were refurbished and then delivered to schools. A district coordinator ensured that consumables were ordered and available for refurbishment, that kits were correctly refurbished, and that kits and live specimens were delivered on time. One center we visited had also taken advantage of volunteers to refurbish kits as well as employing disabled adults participating in a training and placement program.

Our interviews with teachers in districts that used hands-on science instructional materials clearly indicated that the reliability of the system to deliver consumable items and live specimens on time was key for ensuring

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[6] $X^2 = 23.221$, $df = 9$, $p = .006$.

that teachers used the hands-on instructional materials. Teachers reported that they were not likely to incorporate use of hands-on materials if they could not rely on on-time delivery. Teachers and science coordinators also commented that teachers were less likely to use hands-on science instructional materials if the burden of purchasing consumables and live specimens fell largely on them to do on their own time. Therefore, it is critical for districts that expect teachers to use hands-on instructional materials to understand the infrastructure and resources necessary to ensure that these materials are available and used.

Exhibit 3-6
Science Materials Resource Center

Some districts we visited took a coordinated approach. To reduce the cost of the initial purchase of instructional materials these districts created a rotation system whereby they purchased a set of 8- to 10-week hands-on instructional materials of which one third are for earth science, one third are for life science, and one third are for physical science. The districts then created a rotation schedule, dividing the schools into three groups, with one third starting with earth science, another third with life science, and the final third of schools beginning with physical science. The instructional materials sets are then collected, restocked (refurbished) of all consumable items, and sent back out on the rotation. By the end of the school year, each elementary classroom has received three fully stocked instructional materials sets as well as any live specimens required. Although this rotation allows the districts to buy and store fewer consumables, thus reducing costs, it also requires district commitment of infrastructure and personnel to manage the collection, refurbishment, and distribution of materials.

Local Assessments in Elementary Science

Few schools or districts have established local systems to assess and monitor student progress or inform instruction.

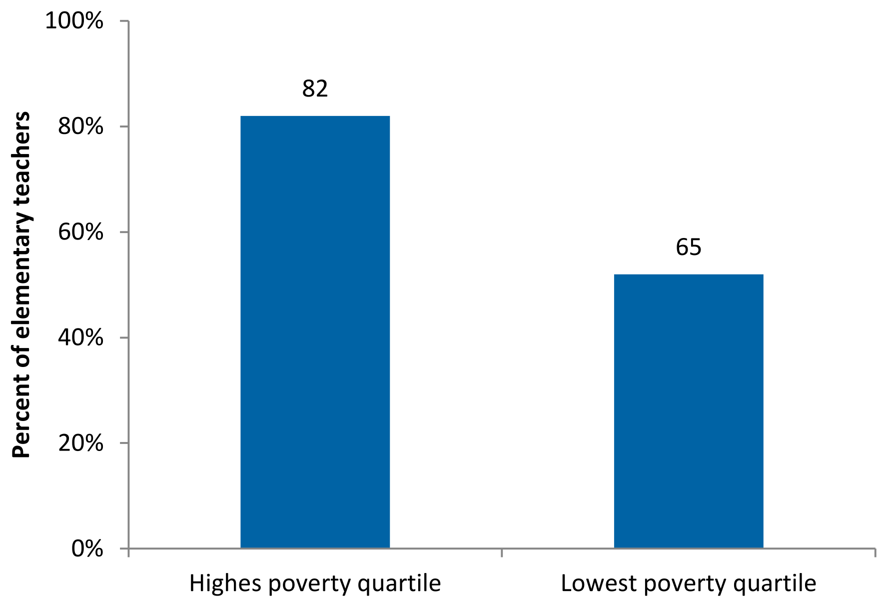
Local educators face a dilemma in terms of science assessment. The California statewide science assessment in fifth grade does not provide teachers and schools with the just-in-time information they need to support

Teachers, principals, and district administrators have no systematic data on students' science knowledge until they have been in elementary school for 6 years.

student learning, guide instruction, or determine teacher professional development needs. It is not useful for formative purposes, nor does it capture all the important learning outcomes related to science. Accordingly, local assessments are one way for districts and schools to monitor students' science learning.[7] Further, local assessments have the potential to help teachers identify gaps in understanding of specific science concepts that are particularly difficult for students to grasp and for teachers to teach. The absence of any systematic local science assessment data in many schools means that teachers, principals, and district administrators have no systematic data on students' science knowledge until they have been in elementary school for 6 years (K–5). Sixty-six percent of California elementary teachers reported that they received little to no support in assessing their students' science learning. Unfortunately, teachers in schools serving higher percentages of students in poverty were more likely report receiving limited or no support for assessing their students' science learning than teachers in schools serving lower percentages of students in poverty (Exhibit 3-7).

Exhibit 3-7
Elementary Teachers Who Receive Too Little or No Support at All in Assessing Student Science Learning, by School-Level Poverty Quartiles

Unfortunately, teachers in schools serving higher percentages of students in poverty were more likely report receiving limited or no support for assessing their students' science learning than teachers in schools serving lower percentages of students in poverty.



Source: 2011 Statewide Science Education Survey of Elementary School Teachers.

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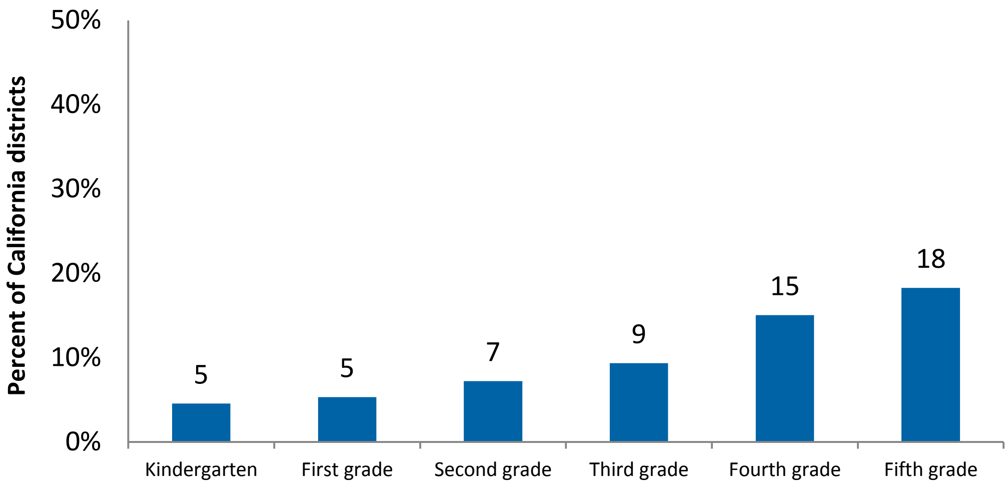
7 Elementary school report cards, especially in the primary grades, may not assign academic grades or standards-based levels (e.g., meets standard, approaching standard) to science.

Yet developing and implementing a local assessment system for science can be challenging for district administrators, even in districts with long-standing elementary science initiatives. More than 60% of California districts do not require local assessments in science,[8] and very few require science assessments in the lower grades (4% in kindergarten). District responses showed a trend (albeit still small) toward requiring local science assessments as students progress through the elementary grades (Exhibit 3-8).

Exhibit 3-8
Districts Requiring Science Assessments in Addition to the State Fifth-Grade Assessment, by Elementary Grade Level



Source: 2011 Statewide Science Education Survey of District Administrators.

There are concerns about introducing additional assessments into an already crowded field of statewide tests.

One challenge schools and districts face is balancing (1) the need to obtain systematic data on student progress with (2) the need to provide teachers with sufficiently tailored data they can act on with (3) the testing burden teachers feel is already overwhelming. In one case study site, the district developed end-of-unit exams to serve both purposes. District staff found them helpful to identify professional development needs, but teachers viewed them as more summative in nature. To address the need for formative assessments that teachers could use to guide instruction during a particular unit of study, the science coordinator began working with teachers in two grade levels (fourth and fifth). These teachers met four times during the 2010–11 school year to develop and share formative science assessments

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8 *Local assessments* in this context refer to assessments that are either developed by the local district (district staff and/or teachers) or purchased by districts to assess student knowledge and skills districtwide. These assessments can take the form of end-of-unit assessments and/or assessments used by teachers throughout a specific unit.

they had created, to discuss results from the assessments, and to pinpoint how the results should guide instruction.

Even with the potential that local science assessments present for districts, schools, and teachers, there are concerns about introducing additional assessments into an already crowded field of statewide tests. In one of our case study districts with a long-standing science initiative, no effort to establish a local assessment system for science is currently under way. A district administrator reported that the district is concerned with the testing burden on students and has not been able to resolve its desire for data with the need to maintain a balance between instruction and assessment.

Summary

For high-quality learning opportunities to exist, the appropriate conditions must be in place. Teachers must be prepared and adequately supported. Instructional materials and essential resources must be available and replenished regularly. Educators, parents, and students must be able to track students' progress relative to clear learning goals. In both the surveys and our case study sites, we found examples of well-prepared teachers, appropriate and well-stocked materials, and informative local assessment systems. Yet overall, we found the general conditions in California elementary schools to be inadequate for the job: teachers without sufficient preparation or support, inappropriate or poorly maintained materials, and lack of systematic assessment data. These conditions result in part from the lack of leadership and inadequate resources dedicated to support high-quality science learning opportunities. We turn to these issues in the next chapter.

CHAPTER 4
SUPPORTING SCIENCE LEARNING

In the preceding chapters, we have described the dearth of high-quality science learning opportunities for elementary students in California and the challenges educators face in attempting to provide such opportunities. Simply put, under current conditions, it is difficult to do science well in elementary school. Teachers need content knowledge they often have not developed in their own education. Students need readily available, hands-on materials that they can use to fully engage in learning science. Everyone needs meaningful ways of measuring student progress to strengthen instructional practice and guide the types of professional development offered to teachers.

Yet we have found and highlighted examples of elementary teachers who have been able to provide high-quality science learning opportunities despite the odds. But widespread adoption of such practices will require leadership and resources. Establishing a coherent instructional system for elementary science that includes the supports necessary to build the content knowledge and pedagogical skills of a teacher workforce while also providing the necessary materials to make science instruction relevant, up-to-date, and interactive will require resources that currently are out of reach for many schools and districts in the state. In such difficult financial times for some schools and districts leveraging external resources has become necessary to build and maintain high-quality science instruction in the elementary grades.

Establishing a coherent instructional system for elementary science…can require resources that are out of reach for many schools and districts.

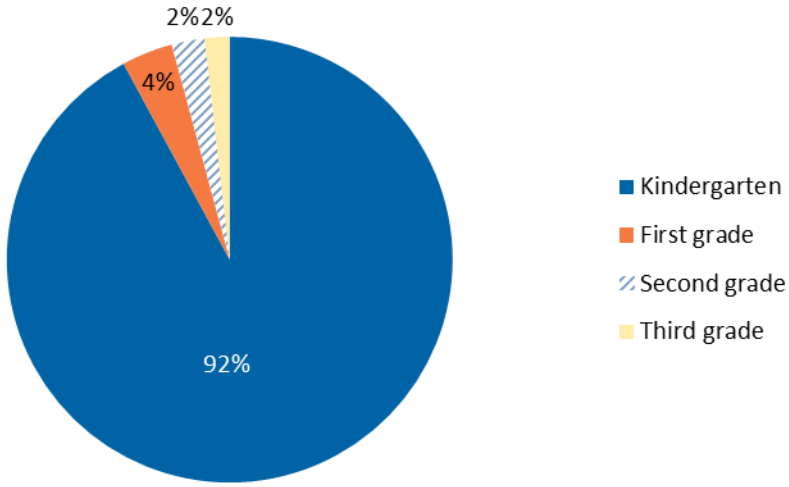
We find that in spite of rhetoric asserting the value of science learning opportunities for elementary school children, most school and district leaders have not initiated major science reforms. We do, however, present some clear examples of districts and schools applying innovative practices to support high-quality science learning opportunities in elementary schools. We also describe how a few districts and schools successfully garner resources and support from external sources that can be useful as a guide for strengthening science instruction across the state.

Leadership in Support of Science Learning

California principals value elementary science education and believe it should begin early.

School leaders believe in the importance of elementary science education. Seventy-seven percent of California elementary school principals surveyed believe that providing all students a strong background in science is essential, with an additional 22% reporting that this is very important. Furthermore, almost all California elementary principals surveyed (92%) believed that science education should begin in kindergarten and all elementary principals believe that science education should begin no later than third grade (Exhibit 4-1).

Exhibit 4-1
Elementary Principals Reporting the Grade Science Instruction Should Begin



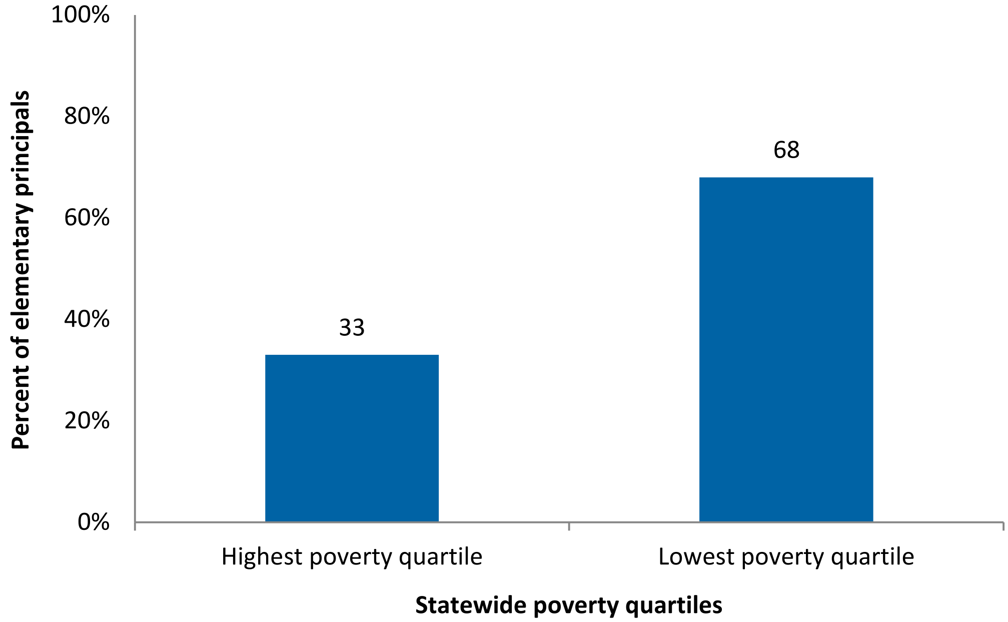
Source: 2011 Statewide Science Education Survey of Elementary School Principals.

Districts and schools lack a support infrastructure for improving science learning opportunities in elementary schools.

Elementary principals in the state's poorest schools were less likely to report that their schools have had significant science initiatives in the past 5 years than principals in more affluent schools.

More than half the California districts (55%) and schools (54%) surveyed have not had any significant elementary science education initiatives in the past 5 years. Even more disturbing, elementary principals in the state's poorest schools were less likely to report that their schools have had significant science initiatives in the past 5 years than principals in more affluent schools. Thirty-three percent of principals in schools serving the highest percentages of students eligible for free or reduced-price lunch reported having significant science education initiatives in the past 5 years. In schools with the lowest percentages of students eligible for free or reduced-price lunch, 68% of elementary principals reported having significant science education initiatives in the past 5 years (Exhibit 4-2).

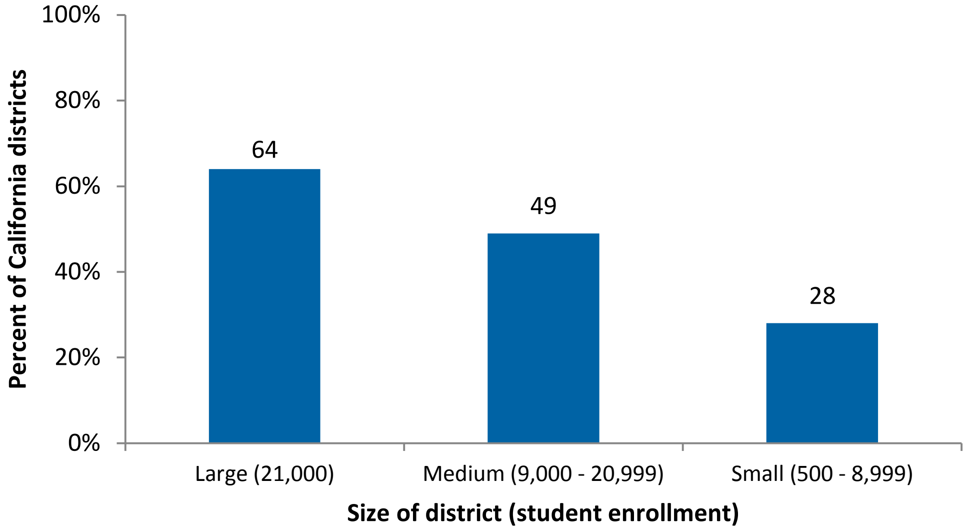
Exhibit 4-2
Elementary Principals Reporting Significant Science Initiatives in the Past 5 Years, by School-Level Percentage of Free or Reduced-Price Lunch



Source: 2011 Statewide Science Education Survey of Elementary School Principals.

Although 61% of district officials reported having policies or suggested guidelines regarding the number of minutes per week science should be taught in elementary classrooms, district support for elementary science is limited. Over 60% of districts had no district staff dedicated to elementary science, with another 13% reporting that they had less than 0.5 full-time equivalent district staff dedicated to elementary science. A closer look at district support by district size shows that large districts were more likely to have staff focused on science than smaller districts, but it is striking that more than a third of large districts had no such staff (Exhibit 4-3).

Exhibit 4-3
Districts with District-Level Personnel Dedicated to Supporting Elementary Science Instruction (Percentage)



Source: 2011 Statewide Science Education Survey of School Districts.

Limited district support for elementary science translates into no capacity to offer professional development for teachers and no access to science specialists or coaches for most elementary schools.

Limited district support for elementary science translates into limited capacity to offer professional development for teachers and little access to science specialists or coaches for most elementary schools. Fewer than 21% of districts provided science-related professional development for elementary teachers. Seventy-five percent of elementary principals reported that their schools do not have access to a science specialist or coach.

Some school and district leaders demonstrate that strong support for elementary science learning is possible.

Aligning district and school practices with a coherent vision is a powerful way to communicate commitment to elementary science.

Even though high percentages of schools and districts reported no significant science education initiatives and few dedicated staff to support instruction, some California schools and districts are supporting elementary science education by developing policies that set direction and communicate expectations. For example, in May 2010 Oakland Unified School District (OUSD) approved a new policy requiring a minimum of 60 instructional minutes for grades K–3 and 90 minutes for grades 4 and 5 beginning in the 2010–11 school year. More minutes alone, of course, will not guarantee that students have the opportunity to engage in high-quality learning during that time. Consequently, the OUSD Science Department also proposed a series of supports to help teachers and schools meet the expectations of the new policy. Fortunately, the new policy brought in funding from philanthropic foundations to help support implementation.

Aligning district and school practices with a coherent vision is a powerful way to communicate commitment to elementary science. In two of our case study schools, district administrators responsible for supporting elementary science are visible at the schools, visiting classrooms, talking to the school principals about elementary science, and keeping principals up to date on which teachers need to attend district-provided professional development on implementing the elementary science instructional materials for their grade levels. To reinforce the importance of elementary science, a principal of one of these two schools instituted additional practices at her school. She dedicates Title I school funds to support family science nights and has asked that all field trips be science based. These practices keep elementary science at the forefront of district and school efforts and communicate to teachers that science is important and should be taught during the regular school day. An elementary school teacher in one of our case study sites reported that science is taught in his/her school because there is an explicit expectation that everyone teaches science. This teacher reported that the superintendent and principal have made clear that science is a priority and that the district science coordinator's classroom visits throughout the year reinforce the district's commitment to elementary science.

Principals and district administrators require leadership development to build their capacity to ensure that high-quality science learning is occurring in elementary schools.

Like teachers, principals and district administrators need support to sustain high-quality science instruction in their elementary schools. Some districts recognized the importance of principals' understanding of high-quality science instruction and building a commitment to teach science in elementary schools. Two districts in our case study sites developed formal strategies for building a common vision of high-quality elementary science instruction as well as for working with principals to support such instruction.

Like teachers, principals and district administrators need support to sustain high quality science instruction in their elementary schools.

In one case study district, the science coordinator provides training specifically to familiarize principals with the science instructional materials and to begin the conversation with these principals about expectations for elementary science instruction. This coordinator also meets annually with school principals to determine how she can support them to ensure that teachers get what they need to implement the science curriculum across the elementary grades.

In another case study district, the science coordinator reported that he often visits classrooms with principals to observe science instruction. He then debriefs with the principals to discuss what high-quality science instruction should look like and what evidence they saw of it during the walk-throughs. This coordinator pointed out that many elementary school principals do not have a science background and tend to equate evidence of doing science activities (e.g., growing plants, posting of student work in science) with high-quality instruction (authentic student-initiated investigations).

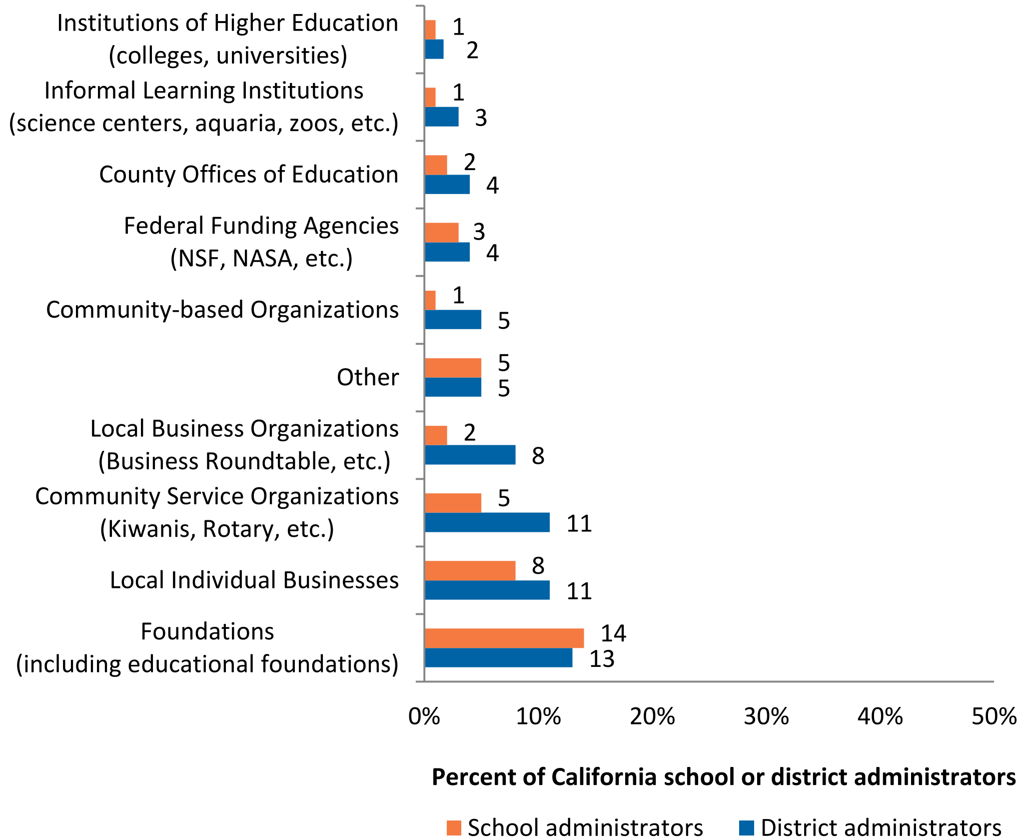
Leveraging Resources to Support Elementary Science

Most schools and districts do not *receive fiscal support for elementary science from external funders.*

Seventy percent of districts and 72% of schools did not receive funds from external funders to support elementary science.

California's economic crisis has resulted in deep cuts to California education, leaving limited funds to support teaching and learning. In this fiscal climate, schools lack funds to support learning; those subject areas not central to state accountability are at greater risk of significant budget cuts. External resources have been the only way for districts and schools to continue to support such subject areas as science. Unfortunately, too few schools and districts have access to such funding sources. Overall, few school or district administrators surveyed across the state reported that external organizations provided funds to support elementary science. Seventy percent of districts and 72% of schools did not receive funds from external funders to support elementary science. For both schools and districts that did report receiving external funds, foundations were the most common source (Exhibit 4-4).

Exhibit 4-4
Districts and Schools Receiving Funds to Support Science Education



Source: 2011 Statewide Science Education Survey of District Administrators and Elementary School Principals.

Only 14% of principals and 12% of district officials reported that foundations provide funds to support their elementary science programs. Local businesses and community organizations also provide funds to a small percentage of districts. Nine percent of district respondents and 8% of school principals reported that they receive funds from local businesses. Eight percent of district representatives and 5% of school principals reported receiving funds from community organizations to support science education in elementary schools.

Districts and schools that were successful in receiving funds from external organizations tended to receive them from just one or two types of organizations (e.g., foundations) than from many different types. Almost all districts (92%) and schools (87%) that received funds from external organizations reported receiving funds from one or two types.

Our case studies suggest that districts and schools rely on grants or donations to support the initial start-up costs of elementary science initiatives as well as their ongoing maintenance. One of the districts in our case studies has been successful in leveraging community resources to help fund its elementary science program (see textbox below).

Leveraging Community Resources to Fund Elementary Science

One of our case study school districts is participating in a science consortium that supports elementary science by providing all the instructional materials needed for K–5 science instruction, including all consumable items and live specimens for hands-on experiments and activities. The consortium also provides professional development on the instructional materials every year to teachers new to the district, teachers changing grade levels, and teachers looking for a refresher course. Although each of the participating districts pays for a portion of the costs, managing such a large program to support approximately 1,300 teachers and 32,000 students requires additional financial support. Besides overseeing the day-to-day operations and providing professional development, the coordinator of the consortium understands that an important part of the job is reaching out to the community to demonstrate the value of the consortium not only to the students, schools, and districts, but also to the companies that will eventually be hiring these students as they graduate from the public schools. The coordinator regularly attends local service organization meetings (e.g., Kiwanis) and invites business representatives and other potential funders to observe elementary science instruction and to tour the facilities where all the hands-on science materials are organized and prepared for delivery to classrooms. The coordinator looks for ways to match the specific interests or goals of local organizations with the consortium’s needs. For example, a business representative was not able to make a cash donation but wanted to support the science program, so the coordinator identified materials needed that the business purchased and donated to the consortium. The coordinator’s outreach efforts have brought in much-needed financial support and also fostered widespread community support for elementary science. The local community knows about the consortium and takes pride in the fact that students have opportunities to learn science throughout elementary school.

Although external funds have provided essential financial support for some elementary science programs, district representatives voiced concern about sustaining elementary science programs as external funding expires.

> We are facing serious challenges once the [grants] run out next year. Our key focus is establishing sustainability programs!

> We are funded through a federal California Mathematics and Science Partnership grant, and with that funding ending and the current budget cuts, science education is going to take a real hit in our district because it's not a priority. We are looking to find private funding to help maintain this level of content professional development to help continue to improve teacher content knowledge and student achievement in science.

> When the grants run out, I am concerned about the sustainability of our strategic plan goals for science.

With a focus on sustaining elementary science programs initially built with external funds, two districts we visited for this study purposely built systems to sustain their efforts for the long term. One provides its services of refurbishing consumable science materials and teacher professional development for a fee to nearby districts. Those fees enable the district to continue to fund district-level positions to support its elementary science initiative. The other district participates in a consortium of districts that not only share the cost of the elementary science program, but also generate revenue by providing their services (including professional development) to neighboring nonconsortium districts for a fee. This revenue helps offset the costs of maintaining a comprehensive K–5 elementary science program. Unfortunately, even these districts have had to cut back on these science programs as district budgets and plans succumb to year-over-year cuts.

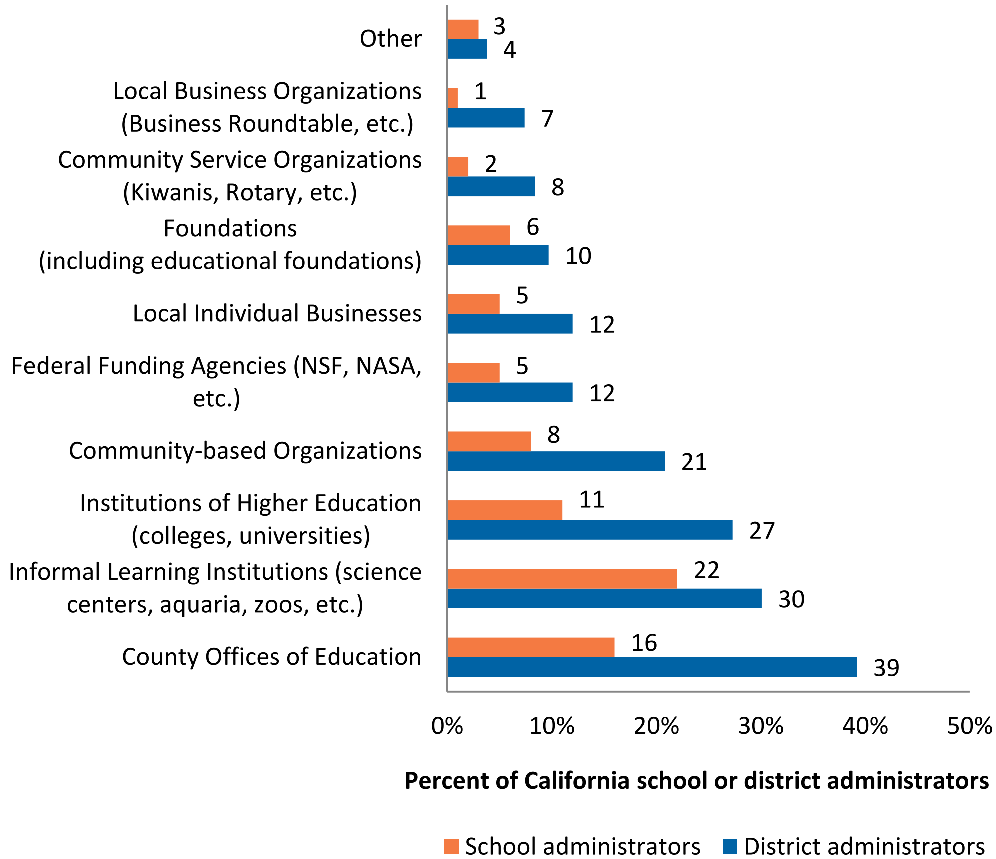
Administrators in our case study schools are also finding ways to combine funding sources, both public and private, to sustain elementary science by dedicating a portion of school site Title I allocations and funds raised by Parent Teacher Associations to support instruction, science-related experiences such as field trips, and family science nights. At one of our case study schools, the principal reported that 13 different budget line items cover the half-time science teacher's salary. The use of volunteers to support elementary science was also mentioned in two of our case study schools as another strategy for sustaining their elementary science initiatives. Volunteers serve in a variety of roles from managing hands-on materials to helping teachers plan science lessons to actually serving as science teachers (especially volunteers with science backgrounds).

In the absence of infrastructure to support the improvement of science education, schools and districts turn to other organizations for critical capacity and expertise.

Sixty-three percent of districts and 48% of school principals in our survey reported receiving support for elementary science from external organizations. County offices of education, informal learning institutions, and institutions of higher education were the external organizations serving the largest percentages of districts and schools. Districts (39%) were most likely to receive services from county offices of education than from the other types of organizations—a trend that is in jeopardy because county services have been dwindling in recent years with decreasing resources.

Thirty percent of districts surveyed received services in support of elementary science from informal learning institutions such as science centers, aquaria, and zoos. For 22% of schools, informal learning institutions were the mostly commonly reported source of services in support of elementary science. Institutes of higher education were the next most likely source, with 27% of districts and 11% of schools receiving services from them (Exhibit 4-5). In addition, access to services from external organizations did not vary by school-level poverty. Elementary schools serving higher percentages of less affluent students were accessing a similar number of external organizations as schools serving higher percentages of more affluent students.

Exhibit 4-5
Districts and Elementary Schools Receiving Services from External Organizations to Support Science Education



Source: 2011 Statewide Science Education Survey of District Administrators and Elementary School Principals.

Our survey results show that districts and schools were more successful at accessing services than funds from a variety of types of external organizations. Over 30% of districts and approximately 20% of principals that received services reported receiving them from three or more different types of external organizations. The percentage of districts and principals receiving funds from three or more external organizations was much lower. Only 8% of districts and 13% of principals reported receiving funds from three or more external organizations.

Districts may have been more successful accessing services from county offices of education; nearly half (44%) had district instructional team members who acted as a liaison between county office of education personnel and elementary schools.

Our case studies revealed that these external organizations provided not only professional development opportunities for teachers, but also direct learning experiences for students. Professional development opportunities were very diverse—from workshops and courses offered on campuses of higher education institutions to training at museums on particular science concepts or standards. Experiences for students varied but were generally praised by teachers, principals, and district administrators as reinforcing science concepts or introducing new science concepts in an experiential or hands-on way. For instance, one of our case study schools partners with the local Audubon Society for environmental education and field trips for students. Through this partnership, students have visited local creeks, the bay, and the ocean. The group even offered field trips for students and their families.

In another example, an external organization developed instructional materials for a local ecology unit for upper elementary grades. The organization provides professional development for teachers in how to use the instructional materials and in how to lead students on a culminating activity, a field trip to study the local ecology. External organization staff members lead teachers through a practice field trip, without the students, so teachers can experience the exact field trip route and learn how to guide the students.

To actively support and foster relationships with external organizations, one of the districts we visited created a science partners network 3 years ago. The network has grown from 15 to 45 organizations that include institutions of higher education, county offices of education, foundations, nonprofit organizations focused on science and the environment, museums, corporations, regional parks, public television and radio stations, and national laboratories. The network meets two times a year to share information about the district's efforts in science and provide partners the opportunity to talk and exchange ideas about how to support the district's science initiatives. The district set up a website with links to partner organization websites as well as agendas and notes from meetings.

Partnerships with Science-Rich Educational Institutions

The West School District has developed several partnerships, including one with a local marine research institute. The institute provides a program that teaches students about watersheds. Fifth-grade students visit the Institute, then develop and conduct investigations related to watersheds. The project takes about a month to complete, and includes researching a topic, designing studies, doing fieldwork in the local community, and creating presentations. In one class, students tested water from different areas (e.g., residential, commercial) to determine how these different areas were affecting water quality in their local watershed. Students then created a presentation and returned to the institute to present their findings to other schools. Students' participation in these investigations allows students to use science to explore issues relevant to their community context.

Summary

Supporting high-quality science learning in elementary schools is demanding, requiring dedicated leadership and resources. In the face of accountability pressures for English language arts and mathematics and scarce funding, districts and schools on the whole do not place a high priority on strengthening science education. However, in our case studies we were able to find exceptions—places where district and school leaders communicated a vision and backed it up with practices to maintain materials and provide appropriate learning opportunities for teachers and principals. These efforts require resources. District and schools that are successful count on external resources, including dollars from external funders and services from external organizations. Unfortunately, far too few districts and schools statewide have been successful in accessing these external resources.

CHAPTER 5
CONCLUSION

California citizens, parents, and educators recognize the importance of education that prepares all students for college and careers. They believe that quality education can help protect our state from continuing economic decline. Californians are particularly interested in science education and believe that it is vital to the future of the state. However, the California education system is far from meeting these ideals. The goal of a "full and balanced curriculum" is unrealized.

Students do not have the opportunities they need to participate in high-quality science learning experiences because the conditions that would support such learning are rarely in place. We estimate that only about one in ten California elementary school students regularly are exposed to the kind of science learning experiences consistent with the emerging national consensus of what is needed. And across the state, teachers simply do not have time in the school day to teach science.

The reasons underlying the lack of high-quality learning opportunities in the state's elementary schools are many. Teachers do not feel prepared to teach science—especially in comparison to their preparation to teach English language arts and mathematics. Unfortunately, districts and schools do not have the resources (staff, time, or funds) to provide the needed professional development. Moreover, high-quality science teaching requires specialized materials, which teachers also say they lack. And again, districts and schools are strapped to provide these resources. Teachers also need systematic feedback on their students' progress in science, but assessment systems that provide such information do not exist in most districts.

These shortcomings are rooted in part in the state and federal accountability systems that place the greatest emphasis on English language arts and mathematics, which consequently receive the lion's share of political and practical attention. In addition, over the past decade, the infrastructure for supporting science education in California has eroded significantly. Statewide programs have suffered with the budget crisis. The end result is that California does not have a coherent system that enables teachers and schools to consistently provide students with high-quality science learning experiences.

In schools and districts, it is imperative to encourage and support educators to use instructional practices that promote the quality and quantity of science learning. During these challenging economic times, leadership and strategically positioned resources are critical. Leveraging both education and community resources is important to strengthen science education. In the long term, as California commits itself to helping to develop national standards in line with the National Research Council's rich vision for science education, the state needs to develop strategies and allocate resources to make that vision a reality.

As a whole, California needs a new road map for supporting science learning in public schools. Policymakers must review and revise the accountability, resource allocation, and support systems that are driving science education out of our public schools. Strengthening science education must be a priority.

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APPENDIX
RESEARCH METHODS

During the 2010–11 academic year, the research team collected original data on science education in California elementary schools. This appendix details the design and procedures for the primary data collection methods and analyses used in this study. Specifically, we discuss the sampling, instrument development, administration, and analysis of the statewide surveys of teachers, principals, and district administrators and the procedures for case study site selection, data collection, and analysis.

Statewide Surveys

Sampling Procedures

Three major surveys were conducted as part of this research:

- Survey of elementary school teachers, enabling the initiative partners to learn more about the quantity and quality of science instruction in classrooms, as well as teachers' attitudes toward and preparation for teaching science.
- Survey of elementary school principals investigating their commitment to and instructional leadership for science at the school level.
- Survey of school district administrators (instructional leadership staff) analyzing information regarding district policies, climate, and support structures for elementary science education.

The surveys of teachers and principals were designed to augment existing data on science teaching and learning in California and gather primary data on topics about teacher preparation and instructional practices. The goal of the school district survey was to gather primary data regarding district policies, climate, and support structures for elementary science education.

Methodology

Two different sampling strategies were used to obtain representative samples of each population of interest (elementary teachers, elementary principals, and K–12 district administrators).

Teacher and principal surveys. The sampling strategy was devised to capture results that are representative of the elementary school teacher and principal populations. The research team used a two-stage cluster sampling strategy to identify the teachers and principals. This strategy entailed randomly selecting 300 California public schools and then randomly selecting up to five teachers at each school. The sampling frame included all the principals from those 300 schools as well as a total of 775 teachers.

District survey. The research team used a stratified random sampling strategy to select the district survey sample. This method is the most precise for obtaining a representative sample of public school districts. The sampling frame included 270 districts. Of the districts in our sampling frame,

- 70 (out of 70) were the districts that serve the largest numbers of students (enrollment of 21,000 or more students) and account for 50% of the students in the state.
- 100 (out of 116) were from medium-size districts (enrollment of 9,000 to 20,999 students) that account for 25% of the students in the state.
- 100 (out of 485) were from small districts (enrollment of 500 to 8,999 students) from the next set of districts that account for 24% of the students in the state.
- The research team did not sample from the smallest 301 districts because they only serve about 1–2% of the population.

An oversample of the surveys in targeted regions enabled the research team to look more closely at key counties or regions and to compare and contrast differences to better inform local policy and educational decisions.

The research team also collected publicly available elementary student achievement and demographic data from participating school districts and schools to enable examination of the relationship between the quality and quantity of science, the available support for science learning opportunities, students' science achievement, and student demographics.

Instrument Development

The process of developing the survey instruments involved several stages. First, the Lawrence Hall of Science studied past surveys used by Horizon, Inc., and adapted items where appropriate. Second, the surveys originally developed for the Bay Area Science Study, conducted by the Lawrence Hall of Science and WestEd in 2006, were reviewed.

The Lawrence Hall of Science developed an original draft of the surveys. These surveys were reviewed by all the partners on the research project, and their feedback was incorporated into the next version. Two district administrators, teachers, or principals, as appropriate, then piloted the revised surveys. Their feedback was incorporated into changes for the final survey.

Survey Administration

The district administrator survey was administered from March to June 2010 using an online survey administration software. First, researchers from the Lawrence Hall of Science contacted all selected districts to determine the name, title, and e-mail address for the most appropriate person. A contact letter was sent to all potential respondents to inform them about the study. Subsequently, e-mail invitations were sent via the online survey administration software. Nonrespondents received regular phone calls and reminder e-mails. The final response rate was 62% for the district survey.

Teacher and principal surveys were administered from March to June 2011. Once the schools were randomly selected, researchers contacted each school to obtain a roster of teachers. If the school had more than five teachers, we used a random number generator to select five teachers; if the school had five teachers or fewer, then all teachers at the school were selected. If teachers' e-mail addresses were available online, we used that roster to randomly select five teachers. E-mail invitations with links to the appropriate survey were sent to the principal and selected teachers. Nonrespondents received regular phone calls and reminder e-mails. The final response rate was 56% for the principal survey and 70% for the teacher survey.

Survey Analysis

All data analysis was conducted using SPSS and SAS software. For the district administrator survey, sample weights were generated and weights were incorporated in all analyses. The analyses began with generating frequency response distributions. Data analysis included disaggregation of survey results by district and school features as well as by student achievement and demographic variables. Comparisons between different groups on categorical variables were made using chi-square tests. T tests or F tests were used where appropriate for comparisons on continuous variables.

Case Studies

The data collection team used case studies to develop a more nuanced understanding of the context and capacity of districts and schools working to teach science across the elementary grades. Through these data, we gained a better understanding of the supports and challenges teachers and school and district administrators encounter as they implement elementary science instruction within a state and federal accountability context that places very little emphasis on elementary science.

The Nomination and Selection Process

Case study schools were collected through a nomination process. Over 60 individuals and organizations across the state were contacted to ask for nominations, including the following:

- Science professional development organizations including the California Science Project and WestEd's K12 Alliance
- The California Science Teachers Association
- Science specialists at county offices of education across the state
- University/district science partnerships including the UCSF Science and Health Partnership and the CalTech Precollege Science Initiative
- Statewide grant programs for elementary science education including the California Mathematics and Science Partnerships and the California Postsecondary Education Commission–Improving Teacher Quality grants program
- Science museums and science centers including the Ruben H. Fleet Science Center, Center for Ocean Sciences, Kidsspace Children's Museum, California Science Center, Monterey Bay Aquarium, Chabot Science Center, Exploratorium, and California Academy of Sciences

A form was developed for nominators to provide basic information about each school or district and reasons for the nominations. We received 20 elementary school nominations and three school district nominations from this process. Because of the relatively few nominations we received as a result of this process, the research team initiated a second process to identify potential case study schools by conducting Internet searches for elementary schools participating in science grants or programs, as well as analyzing the fifth-grade science CST scores to identify elementary schools experiencing success in science as measured by the fifth-grade statewide assessment. Our research and analysis of student achievement resulted in the identification of an additional 21 schools and two additional districts for a total of 46 nominated schools and districts. After eliminating nominated schools with fewer than 50% of their students scoring proficient or advanced on the fifth-grade CST, the research team called the remaining nominated sites to verify that they had efforts in place to teach science across the elementary grades. Districts that were nominated were asked to select one elementary school in their district to participate in the study. Nine schools met the nomination criteria and agreed to participate (Exhibit A-1).

Exhibit A-1
Characteristics of Case Study Schools, 2009–10

School	District size	School enrollment	English language learners (%)	Eligible for free or reduced-price lunch (%)	Proficient or above in science (%)	PI status 2009–10
A	Small	38	0%	68%	64%[1]	Not in PI
B	Large	577	1	10	93	Not in PI
C	Large	420	4	6	95	Not in PI
D	Large	382	52	35	77	Not in PI
E	Large	803	30	82	65	Not in PI
F	Large	235	33	78	91	Not in PI
G	Large	457	8	25	87	Not in PI
H	Medium	716	76	77	79	Not in PI
I	Small	487	35	66	77	Not in PI

[1] Percentage proficient in science for School A is from the 2009 administration rather than the 2010 administration because School A did not have enough students taking the 2010 science CST administration to publicly report the results.

Data Collection

We conducted 1-day site visits at each of the nine schools in winter 2010–11 and spring 2011. On these 1-day visits we interviewed teachers and principals and conducted 20-minute observations in up to six classrooms. Three of our nine case study sites were originally nominated because of their districtwide elementary science efforts. In those three cases, district personnel were also interviewed. We returned to five of the schools for a second 1-day visit in late spring 2011 to conduct longer classroom observations and delve deeper into the supports and challenges teachers, schools, and districts face as they provide opportunities for science learning across the elementary grades. We also collected relevant documents such as handouts, lesson plans, and copies of student science notebooks. In all, we interviewed 35 teachers, 9 principals, 1 former principal, 1 teacher on special assignment supporting science instruction, 1 science aide, 4 science coordinators, and 5 district administrators. Interviews were recorded using digital recording software and notes from interviews were either transcribed or cleaned for accuracy using the digital recordings.

After the site visits were completed, case study research team members drafted case study reports using a structured debriefing form. The debriefing form included key analytic categories such as origins of the science program, implementation, quality assurance, and sustainability.

Data Analysis

Analysis of the qualitative data began with the use of the structured debriefing form. Case study reports integrated the data from all interviews, observations, and any additional information (e.g., lesson handouts, lesson plans, student achievement data) for each case study site. Once the case studies were complete, the research team met to discuss emerging themes and patterns related to elementary science instruction or efforts to teach science across the elementary grades.

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