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Implementing the Next Generation Science Standards

Early Evidence from California

SUMMARY

CONTENTS

Technical appendices to this paper are available on the PPIC website.

The California State Board of Education (SBE) adopted the California Next Generation Science Standards (NGSS) to transform science teaching and learning in K–12 schools in 2013. The new standards emphasize "three-dimensional learning": disciplinary core ideas, crosscutting concepts, and science and engineering practices. Further, they are aligned with the Common Core State Standards to prepare students for college and careers. In this report, we leverage a survey conducted at the end of the 2016–17 school year to examine districts' implementation of the new standards. We find:

- **Implementation is uneven.** Most of the survey respondents are either very familiar (60%) or somewhat familiar (31%) with the NGSS. However, a quarter of respondents in low-performance districts—defined as those in the bottom quartile of student participation in the Advanced Placement exams—are only slightly familiar with the new standards. Seventy-eight percent of districts report that they are implementing the new standards, and the percentage of urban districts reporting this is substantially higher (94%).
- **About half of districts have adopted the SBE's preferred models.** For middle schools, about half of districts opted for the preferred middle school model and close to half have chosen the three-course model (with earth and space science interwoven into each course) for high schools. About 20 percent of districts had not made a decision at the time of the survey, which is a concern given the state's implementation timeline. Rural districts were less likely to have made a decision about middle school courses, while urban districts were less likely to have made a decision for high school.
- **Instructional materials, science labs and equipment, teacher shortage, and teacher training present big challenges.** The state is scheduled to adopt textbooks and other instructional materials in 2018; at the time of the survey (spring 2017), 59 percent of districts reported instructional materials as a big challenge. Most also have issues with the quantity of science labs, the adequacy of science labs, and the quantity of science equipment in their districts. About a quarter of districts reported not having sufficient credentialed science teachers, and more than 70 percent of districts face challenges in teacher training.
- **Successful implementation may require changes in other elements of the K–12 system.** The state's minimum high school graduation requirements include only two years of instruction in life sciences and physical sciences, while NGSS require a minimum of three years of instruction. Local districts can require additional years, but most (60%)

do not. In addition, science education has taken a back seat to math and English and very few students have access to a quality science education in early grades.

The Next Generation Science Standards are an important step toward improving science education; however, the state needs to take additional steps to help districts implement NGSS and prioritize science education. We recommend several actions, including updating statewide high school graduation requirements, incorporating specific science metrics into the state accountability system, and leveraging NGSS to improve science education in the early grades.

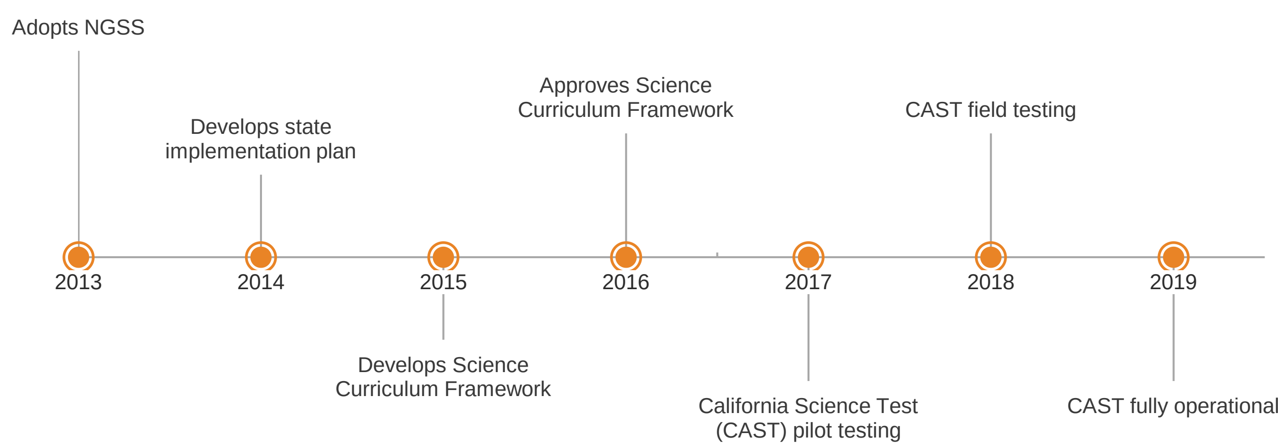
Introduction

The United States lags behind other developed countries in science education (OECD 2015), and within the United States, California is near the bottom on the National Assessment of Education Progress (NAEP) in science. In 2015, average test scores in California were significantly below the national average, and only 24 percent of 4th and 8th graders were proficient, a proficiency rate that has not changed for many years. California also has the largest achievement gaps among student groups defined by race/ethnicity and family income (National Center for Education Statistics 2015).

Over the past decade, policymakers have been rethinking and redesigning science education. Recent reforms have focused on curriculum standards, teacher training, and public perceptions of science education with measurable but uneven results (National Research Council 2009). In 2011 the National Research Council, the operating arm of the National Academy of Sciences, developed a new *Framework for K-12 Science Education*, which identifies the key scientific ideas and practices students should master by the end of high school (National Research Council 2011). The framework serves as the foundation for the Next Generation Science Standards (NGSS), developed by 26 lead states—including California—in collaboration with key stakeholders in science, science education, higher education, and industry (Next Generation Science Standards 2017).

California started its development process in 2011, and the new standards—the California Next Generation Science Standards—were adopted by the State Board of Education in 2013 (Senate Bill 300 2011). The California Science Test (CAST), a new NGSS-aligned assessment, will be fully operational in 2019. Figure 1 summarizes the key milestones in the development and implementation of NGSS in California. Today, 18 states and the District of Columbia, which together serve more than 35 percent of the nation's K–12 students, have adopted the NGSS (National Science Teacher Association 2017).

FIGURE 1
NGSS Timeline in California

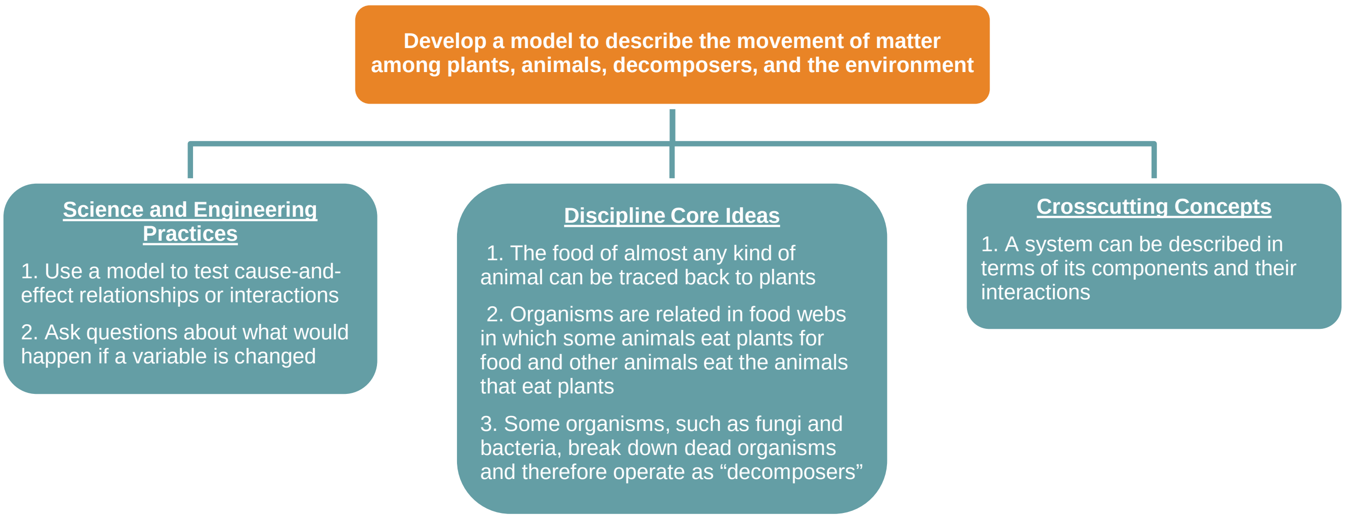


SOURCE: California Department of Education, various years.
NOTES: Awareness phase: 2013–2015; transition phase: 2015–16; implementation phase (2016–17).

The Next Generation Science Standards differ from the previous science standards in a few ways. First, they are internationally benchmarked against countries whose students perform well in science and engineering (e.g., Singapore, Finland, Japan, Canada, China, and South Korea). Second, the standards integrate three-dimensional learning, which connects scientific and engineering practices, crosscutting concepts, and disciplinary core ideas to prepare students for success in college and career (Figure 2). Third, they apply to *all* students and *all* science disciplines, not just the areas covered by state testing or required for high school graduation. Fourth, the new standards are fully aligned with the new math and English standards, which means that they integrate skills used in math and language arts to improve student learning in all three disciplines (Next Generation Science Standards 2017).

FIGURE 2

An example of three dimensional learning in grade 5



SOURCE: National Science Teachers Association, 2017.

This paradigm shift has profound implications for science education—from instructional materials, to teacher training, to student assessment. Across the state, districts have high hopes for NGSS, as 38 percent of districts think that the new standards will very likely lead to an improvement in student science achievements, and the share of high-need districts holding this view is substantially higher (47%).[1] Districts see a variety of challenges and opportunities as they implement the new science course sequence, the new science assessment, and new instructional materials.

In this report, we examine the state's progress in NGSS implementation, identify the challenges districts have encountered, and offer recommendations for state and local policymakers. Our primary data source is a survey we administered at the end of the 2016–17 school year (spring 2017). Our survey sample includes responses from 204 (49%) of the state's unified and high school districts.[2] Forty-seven percent of respondents are district or school administrators (e.g., heads of departments of curriculum, school principals), and 37 percent are science

[1] High-need districts are those in which at least 55 percent of the students are low income, English Learners, and/or foster youth.

[2] We exclude elementary districts from this report for two reasons. First, because the sample is small and unrepresentative, it is hard to reach any meaningful conclusions. Only 49 elementary districts responded to our survey and there is a substantial selection issue in the respondent sample. For instance, large, urban, affluent districts as well as districts with more qualified teachers and Latino students were more likely to respond to our survey (Technical Appendix D). Second, some of the policy relevant discussion, e.g., course sequence, are applicable to middle and high schools. For early evidence on NGSS implementation in earlier grades, e.g., elementary schools, please refer to work from the California NGSS K–8 Early Implementation Initiative.

teachers (e.g., science head).[3] We supplement the survey with administrative data from the California Department of Education, the National Center for Education Statistics, and the Census.

Tracking NGSS Implementation

NGSS implementation in California was designed to be a three-stage process: the awareness phase (2013–15), the transition phase (2015–16), and the implementation phase (2016–17). During the awareness phase, the state introduced the new standards, developed implementation plans, and established stakeholder collaborations. The transition phase concentrated on needs assessments and resources/capacity building. The implementation phase focused on fully aligning curriculum, instruction, and assessments with NGSS (California Department of Education 2014). Local activities during the implementation stage include providing professional development for teachers, adopting new instructional materials in classrooms, and implementing programs to support new instructions in classrooms (California Department of Education 2017). The state timeline serves as a guideline; local districts, depending on their needs, developed their own implementation plans. For instance, in many cases the awareness phase and the transition phase have been merged or both have been folded into the implementation phase. For this reason, we focus primarily on the implementation phase.

Awareness Levels Are High

An overwhelming majority of respondents are either very familiar (60%) or somewhat familiar (31%) with the CA NGSS, and the awareness level is substantially higher than that of the previous standards (Banilower, Smith, and Weiss 2002). District administrators (e.g., curriculum heads) are more likely than school administrators to be aware of NGSS; this is not surprising, given that they are usually in charge of district-wide initiatives.

However, there is important variation across districts. Respondents in less than half of low-performance districts—defined in this report as those in the bottom quartile of Advanced Placement (AP) exam participation distribution—are very familiar with the standards, and about a quarter of respondents in these districts are only slightly familiar with the new standards.[4] The relatively low level of awareness raises concerns about implementation (Figure 3).

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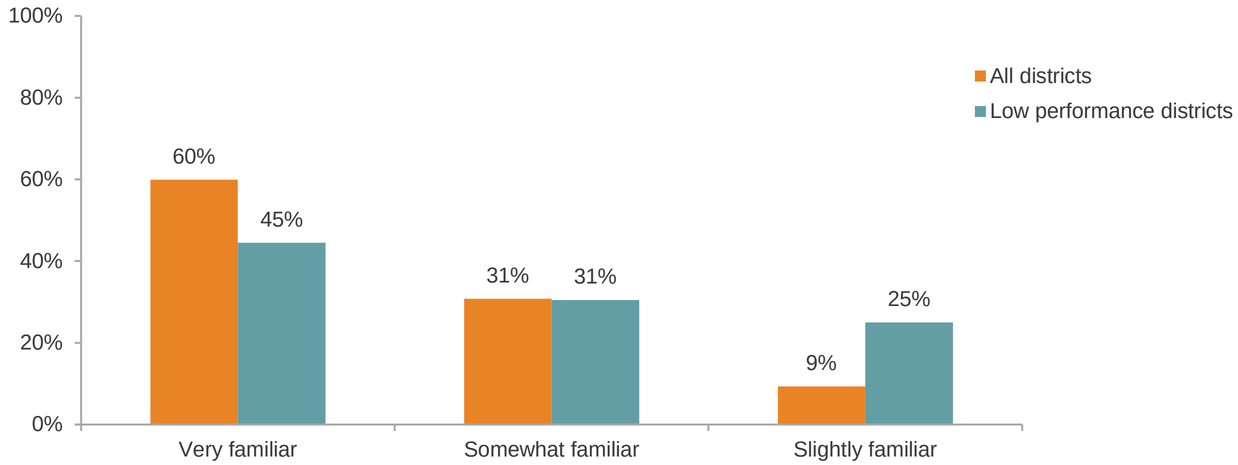
[3] Our weighted sample is not different from statewide averages across a wide range of student, school, teacher, district, and neighborhood characteristics. We report districts' response weighted by their inverse probability of responding to our survey in order to control for the selection problem in districts' response. A detailed discussion about our survey (including weighting) is included in Technical Appendix A, and a copy of the survey instruments is included in Technical Appendix D.

[4] We also consider alternative measures of district performance that include a–g completion rate, % students scoring proficient or above on AP exams, % students tested in California Standardized Test (CST) science, and mean scale scores on CST science. Because of the variation in a–g courses across districts (e.g., instructional quality, grading policy, etc.), we found that AP participation rate is a much stronger predictor of CST scale scores. However, since CST have been discontinued, we use AP participation to measure district performance.

FIGURE 3

Most districts are familiar with the NGSS, 2016–17



SOURCE: District familiarity: PPIC NGSS survey, 2017. % students (grades 10–12) participating in at least one Advanced Placement (AP) exam: California Department of Education, 2015–16.

NOTE: Weighted responses from 204 unified and high school districts. Low-performance districts are those in the bottom quartile of Advanced Placement (AP) participation. We perform an ordered logit regression that includes district enrollment, geographic location, share of high-need students, student performance, district type, and respondent positions; we report the subgroup results only if the group indicator (student performance) is significant (see Technical Appendix B).

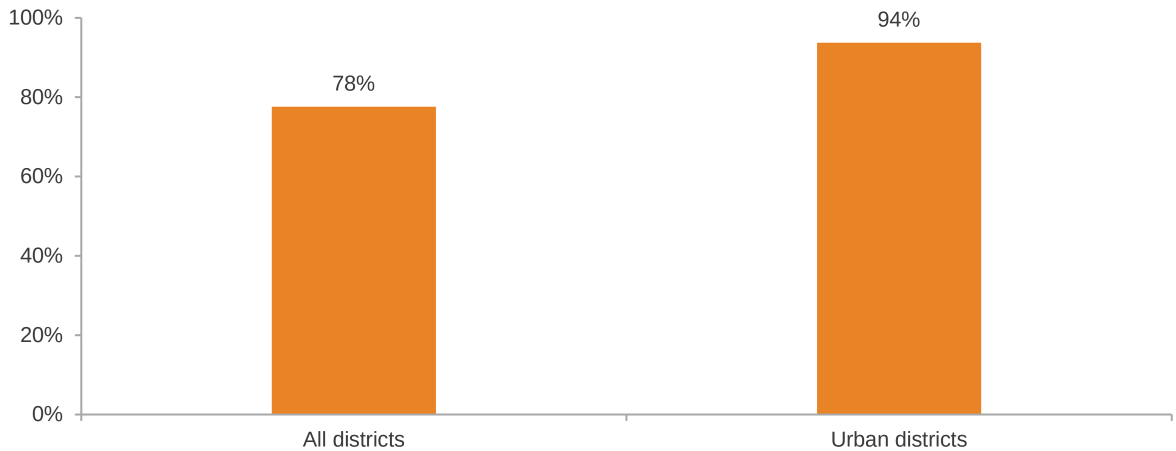
Implementation Is Uneven

According to the state's implementation timeline, all districts were to have rolled out their implementation between 2016 and 2017. At the time of this survey, 78 percent of districts reported that they were implementing the NGSS; the share of urban districts is substantially higher (94%), even after controlling for the fact that awareness is higher in these areas (Figure 4). There are no clear consequences for districts that did not implement the standards by 2017, though NGSS implementation may be included in the state's new accountability calculation as part of its Priority 2 State Standards (Conditions of Learning), and schools and districts missing the performance target are eligible for technical assistance and/or intensive intervention (California Department of Education 2017).

It is worth noting that familiarity with and implementation of NGSS are a necessary but not sufficient condition for meaningful changes in instructional practices in classrooms. Studies on the implementation of the previous standards have found that teachers who said they were implementing the new standards were no more likely to be using standards-based practices than teachers who were not implementing the standards (Banilower, Smith, and Weiss 2002). For this reason, we need to look at districts' progress in choosing new science course sequences, adopting new instructional materials, and providing professional training for teachers.

FIGURE 4

Almost all urban districts are implementing the NGSS, 2016–17



SOURCES: District response: PPIC NGSS survey, 2017. District geographic location: National Center for Education Statistics, 2013–14.

NOTES: Weighted responses from 204 districts. We ran a probit model that includes district enrollment, geographic location, share of high-need students, district type, student performance, and familiarity with NGSS standards; we report the results only if the group indicator (urban, in this case) is significant (see Technical Appendix B).

Districts Have Multiple Science Course Sequence Options

NGSS are organized by grade levels for kindergarten through grade 5 but are *banded* at the middle school (grades 6–8) and high school (grades 9–12) levels. The standards specify what students should know and be able to do but do not prescribe any particular teaching method, leaving districts with a number of course sequence options.[5] For instance, the same discipline core ideas (DCIs) such as earth and human activity could be taught in multiple grades or in a single grade.

Middle schools may choose an integrated learning progression model (three courses that cover multiple scientific disciplines) or a discipline-specific model (three courses that each address one scientific discipline). Table 1 illustrates the difference between an integrated and a discipline specific model. In the discipline-specific model, physical science discipline core ideas (DCIs) are taught exclusively in 8th grade, while in the integrated model, the DCIs are taught across grade levels. In 2013, the SBE chose the integrated sequence as its preferred model; it was developed and recommended by the Science Education Panel, which concluded that it would be the most effective model for optimizing student learning (California Department of Education 2016). Districts, however, have the authority to choose the NGSS-aligned model that works best for their students. Similarly, high schools may choose a three-course model (e.g., biology, chemistry, physics, with earth and space science integrated into each discipline), a four-course model (with earth and space science as a separate fourth course), or an integrated model (every science area, every year). Districts' choices may reflect their pedagogies, community values and beliefs, resources and capacities, as well as student needs (Tanner and Tanner 2006).

[5] At the elementary level, students are introduced to multiple core ideas and crosscutting concepts in each grade.

TABLE 1

Arrangement of selected science disciplinary core ideas (DCIs) under NGSS

Disciplinary core idea		Subtopic	Integrated (preferred)			Discipline specific		
			6	7	8	6	7	8
Earth and Space	Earth and Human Activity	Global climate change causes	X			X		
		Resources availability		X		X		
		Natural hazards		X		X		
		Resource consumption			X	X		
Life	From Molecules to Organisms: Structures and Processes	Cells and body systems	X				X	
		Photosynthesis and respiration		X			X	
Physical	Energy	Kinetic energy and collisions	X		X			X
		Heat and heat flow	X					X
		Potential energies and gravity			X			X

SOURCES: Chapter 5. Grades Six Through Eight Preferred Integrated Model, 2016 Science Framework for California Public Schools Kindergarten through Grade 12.

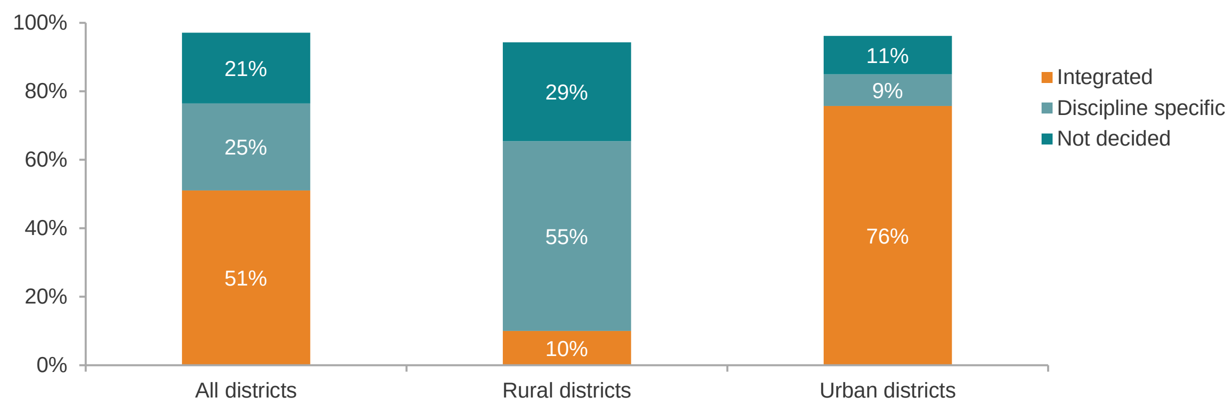
Choosing NGSS-aligned science courses in middle schools

Aligning science curricula with the new standards is among the important milestones in NGSS implementation. About half of districts responding to our survey chose the SBE-preferred integrated learning model for middle schools, while a quarter stuck with the traditional discipline-specific model and 21 percent were still undecided by the end of the 2016–17 school year. Most urban districts adopted the integrated model (76%), while rural districts that have adopted a model tended to opt for the traditional sequence. Notably, close to a third of rural districts were still undecided (Figure 5).

The divide between urban and rural districts in middle school sequence has important implications for student outcomes. If the state is correct that the integrated model is more effective, students who learn science via the traditional method may be left behind.

FIGURE 5

Science course sequence in middle schools under NGSS, 2016–17



SOURCES: Middle school science course sequence: PPIC NGSS survey, 2017. District geographic location: National Center for Education Statistics, 2013–14.

NOTES: The numbers in each column may not add up to 100 percent due to the exclusion of "don't know," "other," or skipped responses. Responses are weighted by inverse probability of responding (Technical Appendix A). We perform a multinomial logit regression that includes district enrollment size, geographic location, high-need students share, student performance, and familiarity with NGSS. The base outcome is "not decided" and we report subgroup results only if the group indicator (rural, urban) is significant (see Technical Appendix B).

Choosing NGSS-aligned science courses in high schools

Our survey shows that 23 percent of all responding districts had not selected a course sequence by the end of the 2016–17 school year; the share of undecided urban and high school districts is close to 30 percent. Students in these districts may not have enough time to learn the materials that will be covered in the new assessments, which will be field tested in spring 2018. Most of those that had made a decision chose the three-course model (Table 2).

In high schools, the course sequences chosen by districts could affect how students fulfill the a–g course requirements in order to be eligible for the University of California (UC) or the California State University (CSU).[6] The current "d" requirement (laboratory science) includes two years of instruction in at least two of the three disciplines of biology, chemistry, and physics, while under NGSS there are four core categories—physical science; life science; earth and space science; and engineering, technology and applications of science. To align with NGSS, UC proposes to change its "d" requirements to three years—it will continue to require two years of coursework in two of the three core disciplines but will give students the option to take a third course in disciplines covered by the NGSS, such as earth and space sciences, computer science, engineering, and applied sciences. If the change is approved, students entering high school in fall 2019 will be the first cohort subject to these requirements.[7] Students in schools with a three- or four-course model are more likely to follow their school's chosen sequence and less likely to take a third course outside of the three core disciplines.

TABLE 2

Science course sequence in high schools under NGSS, 2016– 17

	All districts	Rural districts	Urban districts	High school districts
3 course	47%	52%	50%	41%
4 course	17%	26%	5%	17%
Not decided	23%	18%	29%	33%
Own model	8%	0%	11%	10%

SOURCES: High school science course sequence: PPIC NGSS survey, 2017. District geographic location: National Center for Education Statistics, 2013–14.

NOTES: The numbers in each column may not add up to 100 percent due to the exclusion of "don't know," "other," or skipped responses. About 1 percent of districts opted for an integrated model (every science area, every year). Numbers are weighted by inverse probability of response (Technical Appendix A). We perform a multinomial logit regression that includes district enrollment size, geographic location, high-need student share, student performance, and familiarity with NGSS. The base outcome is "not decided" and we report subgroup results only if the group indicator (rural, urban, high school district) is significant (see Technical Appendix B).

NGSS and accelerated science pathways

One of the big concerns about the Next Generation standards was that they might not allow students to take accelerated pathways to higher-level science courses (e.g., advanced placement). However, about two-thirds (66%) of respondent districts do offer accelerated pathways that are aligned with NGSS, and an overwhelming majority of these districts have open enrollment policies—they do not have GPA or other requirements for students who want to enroll in courses (Figure 6). Districts that have opted for an integrated science sequence are as likely as those with a traditional sequence to offer accelerated pathways.

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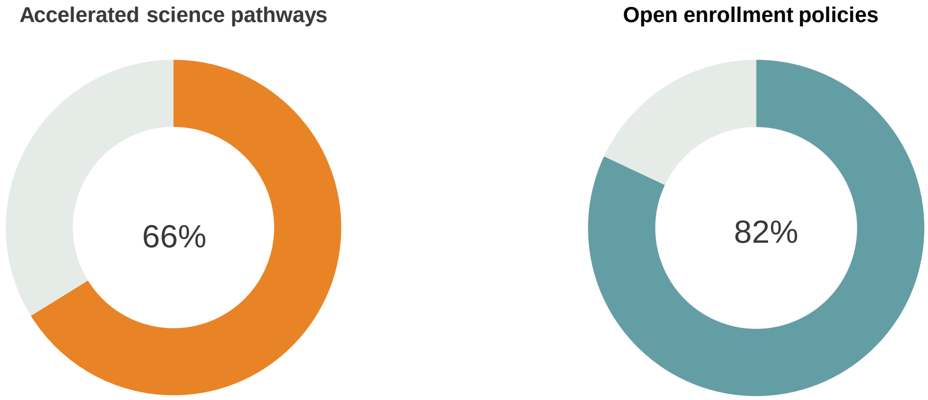
[6] For more on the a–g requirements, see the a–g guide on the University of California Office of the President (UCOP) website and CSU's admission requirements.

[7] The changes were proposed by the Board of Admissions and Relations with Schools (BOARS) and approved by the Assembly of the Academic Senate at its February meeting. The Board of Regents may consider it at their spring meeting. CSU is developing similar requirements.

FIGURE 6

Most districts offer accelerated pathways under NGSS



SOURCE: NGSS Survey, PPIC, 2016–17.

NOTES: Weighted responses based on 204 school districts. High school districts are somewhat more likely to have open enrollment policies (96%). No significant variation by district enrollment size, geographic location, performance, or science course sequence (see Technical Appendix B).

Instructional Materials

Quality instructional materials are an important component in the implementation of the new science standards. The science framework adopted by the State Board of Education in November 2016 includes directions for publishers and guidelines for the adoption of instructional materials for grades K–8 and 9–12. However, fully developed programs are in short supply (Bybee and Chopyak 2017). Several entities, including the California Department of Education, the County Superintendents Educational Services Association, the National Science Teachers Association, and Achieve, also released tool kits to guide districts' review, pilot, and adoption process.[8] The state has fallen behind schedule but is expected to release its list of recommended instructional materials in 2018.

In the absence of the state list, it is not surprising that most districts in our survey reported difficulty in selecting instructional materials. More than half of responding districts view instructional materials as a big challenge, and those opting to develop and adopt their own materials usually do not have enough resources to complete the adoption process in a short period of time—the new standards-aligned assessments will be field tested this spring and become fully operational in 2019. Implementation of the new math and English standards shows that teachers often struggle to implement high standards when they do not have a comprehensive curriculum in place (Kaufman et al. 2016).

Labs and Equipment

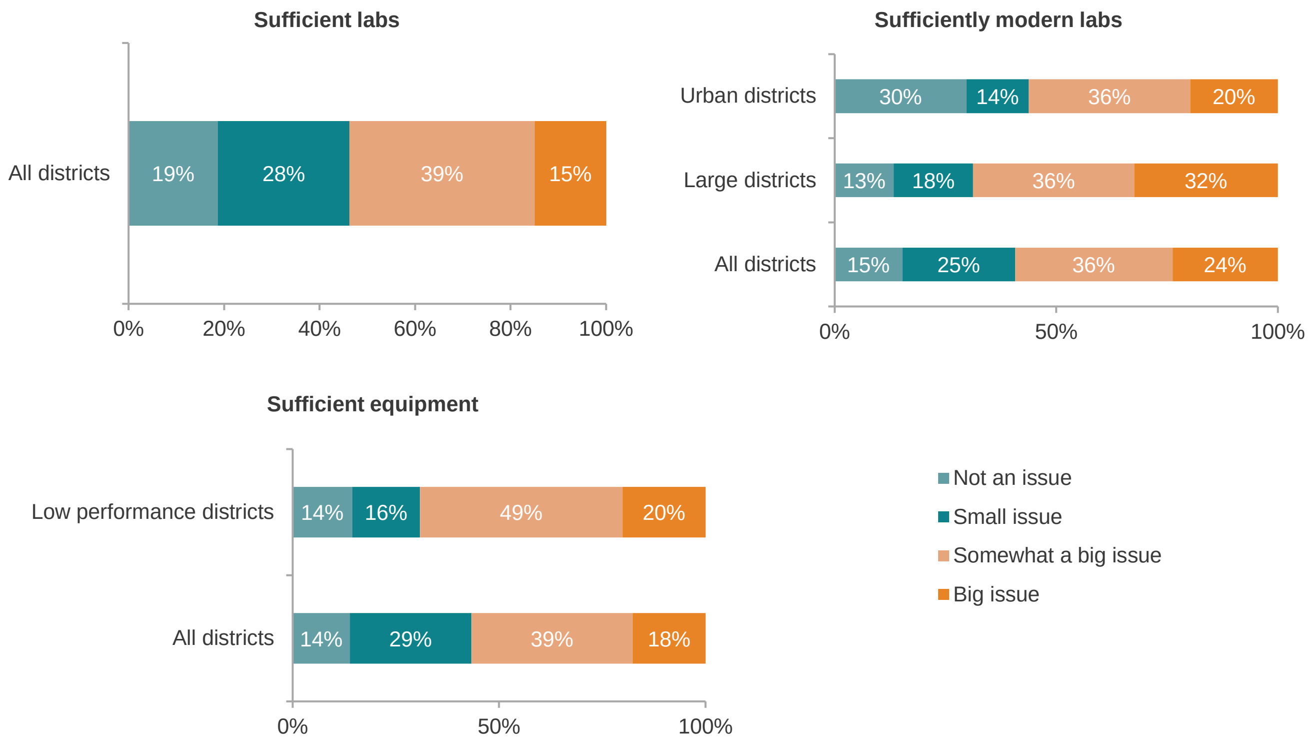
Under NGSS students need opportunities to carry out science investigations and solve engineering design problems, and access to science labs and specialized equipment can help to provide students with these opportunities. More than half (54%) of districts reported that the number of science labs is either a big issue or somewhat of an issue, with no significant variation across districts (Figure 7). An even higher share of districts reported issues with quality: 60 percent do not seem to have labs that are modern enough to accommodate science learning in the 21st century. Large districts are more likely to have this problem (68%). Fifty-seven percent of

[8] Examples include the Educators Evaluating the Quality of Instructional Products (EQuIP) developed by Achieve and the National Science Teachers Association, the Primary Evaluation of Essential Criteria (PEEC), another tool developed by Achieve, and the Next Generation Analyzing Instructional Materials (Next Gen AIM), developed by Biological Sciences Curriculum Study, Achieve, and the K–12 Alliance at WestEd.

districts also report that the quantity of science equipment is a big issue or somewhat of an issue; this concern is more widespread among low-performance districts (69%).

FIGURE 7

Sufficient science labs and equipment are challenges for most districts



SOURCES: District responses: PPIC NGSS survey, 2017. District enrollment size: California Department of Education, 2016–17. % students (grades 10–12) participating in at least one Advanced Placement (AP) exam: California Department of Education, 2015–16. District geographic location: National Center for Education Statistics, 2013–14.

NOTES: Sample includes weighted responses from 204 school districts. For each panel ("has sufficient labs," "labs modern enough," and "sufficient equipment"), we perform an ordered logit regression that includes district enrollment, geographic location, share of high-need students, district type, and student performance; we report subgroup results only if the group indicator (large, urban, performance) is significant (see Technical Appendix B).

Science Teacher Shortages and Larger Class Sizes

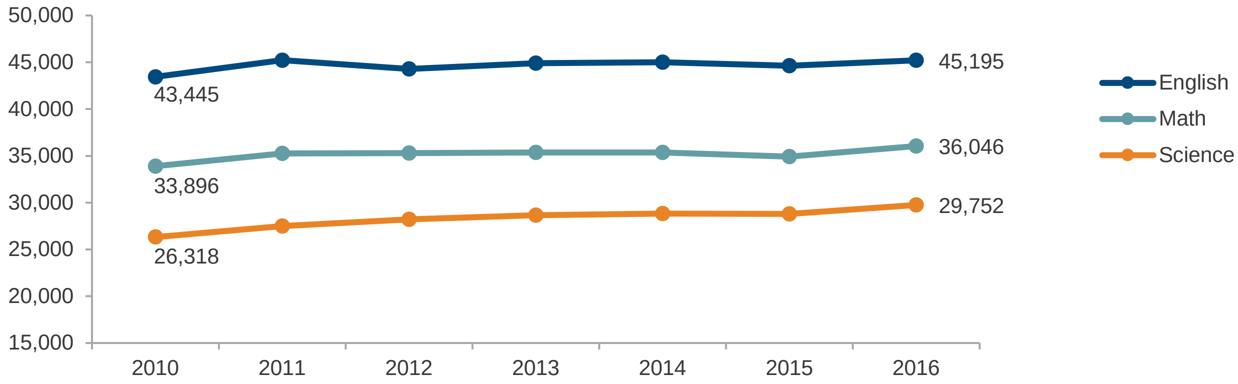
About a quarter of districts reported that they do not have enough credentialed teachers to teach the NGSS, with no significant difference across district characteristics and course sequence choices. Indeed, the state has been grappling with the teacher shortage problem for years. Despite a steady increase over the past two decades, there are not as many teachers in science as there are in mathematics or English language arts (Figure 8). As a result, the average science class size tends to be much larger than that of other subjects (Figure 9).[9] Most respondents stated that large class size has been a big challenge (38%) or somewhat of a challenge (22%); the problem is more prevalent in large districts (74%).[10]

[9] Another significant factor affecting teacher shortage is teacher mobility or retention. While we do not have statewide data, in our survey, most districts reported having a better time in retaining teachers but more difficulty in hiring new teachers.

[10] Another concern is that some teachers may not have the credentials to teach integrated science. However, this does not appear to be a significant issue, as statewide most (>90%) science teachers earned a credential that includes an authorization for teaching introductory, general and integrated science in grades K− 8. That said, it may have a bigger impact on individual districts. For instance, some districts may have a larger share of teachers holding specialized science license, given that these credentials are created to attract second-career science teachers.

FIGURE 8

Schools have fewer science teachers

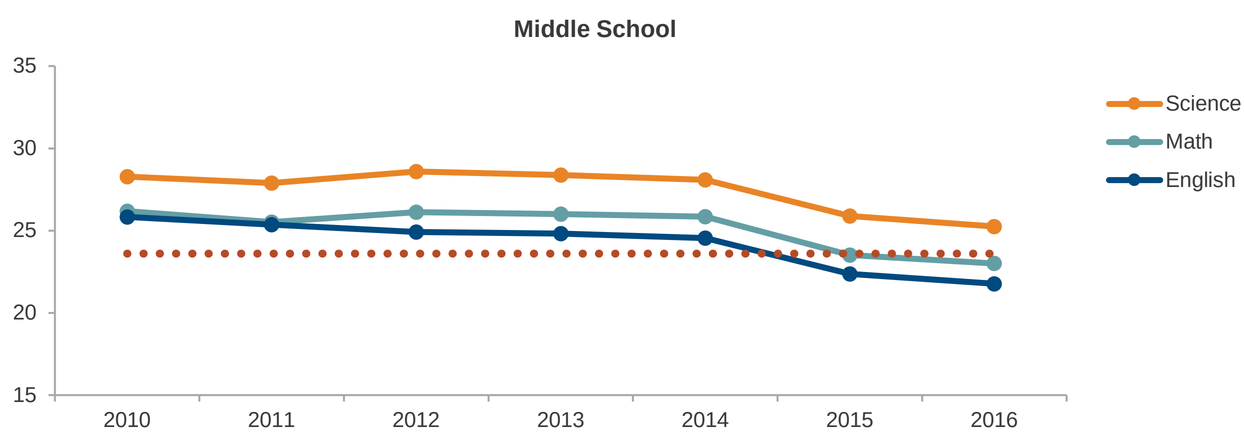


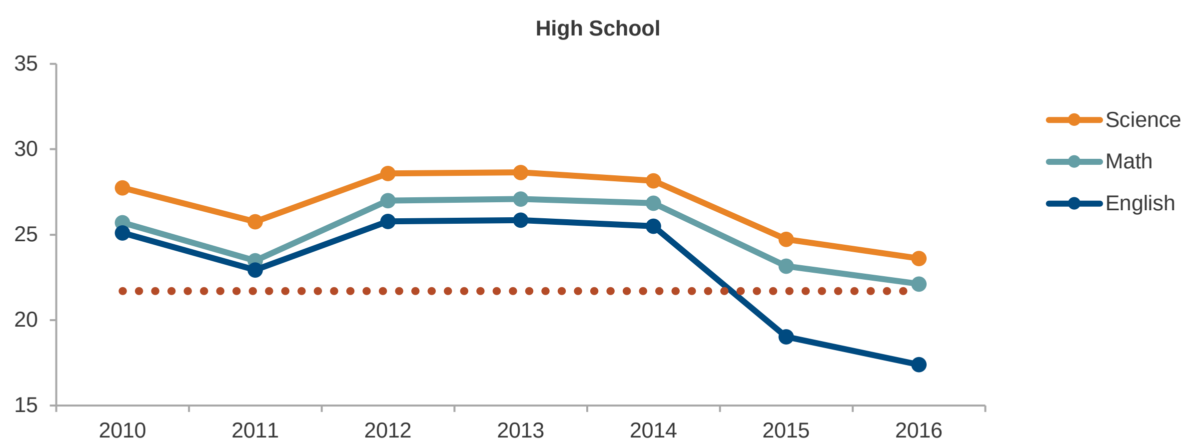
SOURCE: California Department of Education, Staff Assignment Files, 2010–11 to 2016–17.

NOTES: Teachers in departmentalized instruction only (i.e., not teaching in self-contained classrooms, which is typically the case in elementary schools). High schools have experienced a larger increase in the number of teachers in later years (Technical Appendix B, Figure 1). Includes any teachers who taught a math/science/English classroom in a given year. Not all teachers have the necessary credentials —some may be assigned to subject areas for which they do not have the right credentials. During the 2016–17 school year, 27,083 teachers are certified to teach middle/high school science.

FIGURE 9

Average class sizes are larger in science





SOURCES: Average class enrollment, California Department of Education, 2010–16. National average: Horizon Research, Report of the 2012 National Survey of Science and Mathematics Education, 2012; Schools and Staffing Survey, 2011–12, National Center for Education Statistics.

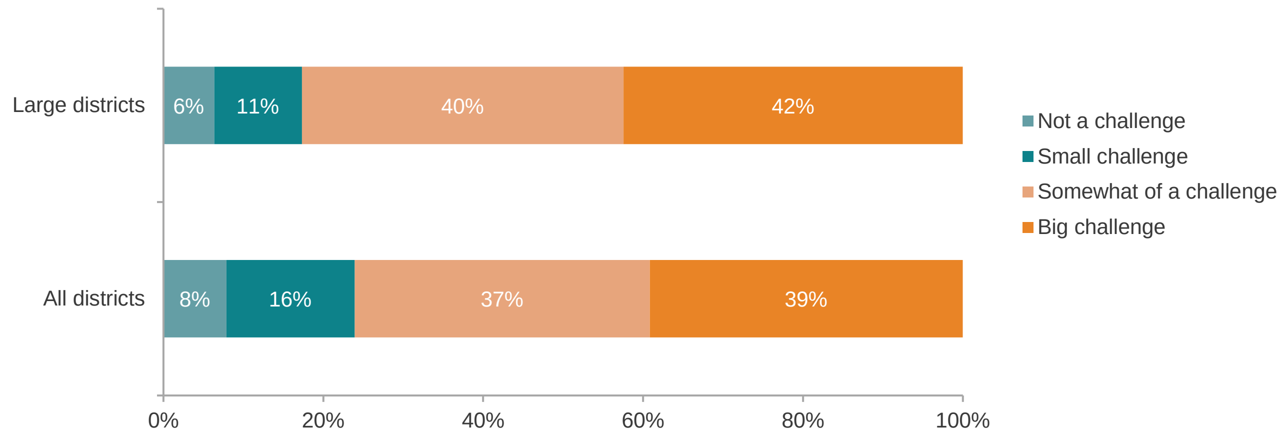
NOTES: Average enrollment in elementary classes (i.e., self-contained classrooms) is 23 in California; the national average (indicated by the dotted red line) is 22.

Most Districts Face Teacher Training Gaps

In addition to persistent teacher shortages, an overwhelming majority of districts face training gaps, as most of their teachers are not well prepared to teach to the new standards (Figure 10). Thirty-nine percent of responding districts cited insufficient teacher training as a big challenge and 37 percent reported that it is somewhat of a challenge; among large districts, these percentages are slightly higher.[11] This has important implications for NGSS implementation in classrooms: without sufficient training, teachers may not be prepared to align instruction with the new standards.

FIGURE 10

Most districts report insufficient training as a challenge



SOURCES: District response: PPIC NGSS survey, 2017. District enrollment size: California Department of Education, 2016–17.

NOTES: Sample includes weighted responses from 204 school districts. We perform an ordered logit regression that includes district enrollment, geographic location, high-need students share, student performance, and district type. We report subgroup results only if group indicator is significant. For "insufficient teacher training," we also include a variable indicating whether respondents think that their districts have enough teachers (see Technical Appendix B).

Aligning Other Components of the K–12 System

NGSS implementation is an important step toward improving science learning, but it will not be successful unless the state makes changes to other elements of the K–12 system, including statewide high school graduation requirements, resources for science education, and the prioritization of science education in early grades.

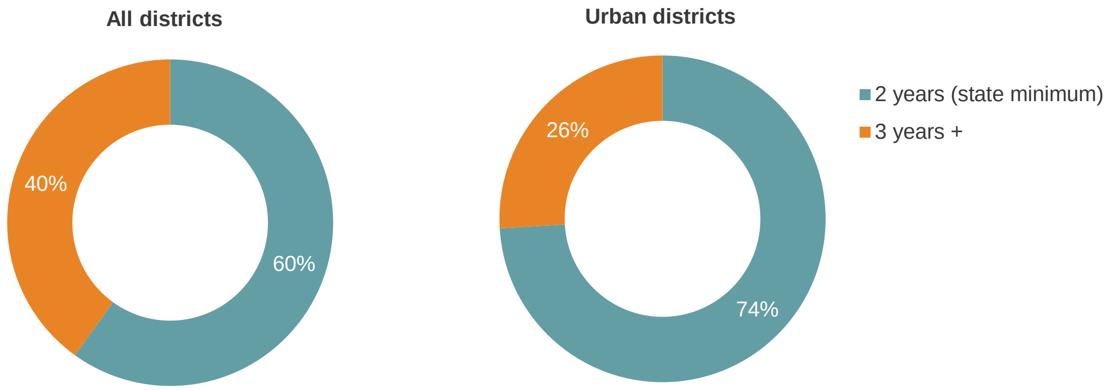
High School Graduation Requirements Are Not Aligned with NGSS

The state sets minimum high school graduation requirements that districts can supplement. The state's current science requirements, adopted in 1998, mandate two years of science; however, the new science standards require a minimum of three years. During the 2016–17 school year, 40 percent of districts required an additional year (or more) of science; only 26 percent of urban districts did so (Figure 11).[12] This has raised concerns that districts requiring only two years of science may not be able to fully implement the new standards in the classroom. It also raises important equity concerns: the variation in high school graduation requirements may lead to inequitable learning opportunities.

[11] Among districts with enough science teachers, 32 percent cited insufficient training as a big challenge and 32 percent reported that it is somewhat of a challenge.
[12] Only two districts reported that they are in the process of changing their graduation requirements from two years to three years.

FIGURE 11

Most districts do not require additional years of science instruction for high school graduation



SOURCES: District response: PPIC NGSS survey, 2017. District type (high school district versus unified): California Department of Education, 2016–17.

NOTES: Sample includes weighted responses from 204 school districts. We perform a probit regression that includes district enrollment size, geographic location, high-need students share, student performance, and district type. We report subgroup results only if the group indicator (urban) is significant (see Technical Appendix B).

California has not revised its minimum science graduation requirements since 1998. Over the past decade, most states have made significant changes to their high school graduation requirements, leaving California one of a few states that require only two years of science (Figure 1, Technical Appendix C). The state's graduation policy has contributed to low levels of participation in science courses (Gao and Johnson 2017). The state must cover the costs of new mandates. However, the benefit of aligning state graduation requirements with the NGSS may outweigh the cost. Such a change could also address the equity concerns that arise when districts choose not to align their graduation policies with NGSS. Raising high school graduation requirements is not likely to improve student outcomes in and of itself; it should be combined with additional support and advising to ensure that *all* students benefit.

Resources for Science Education

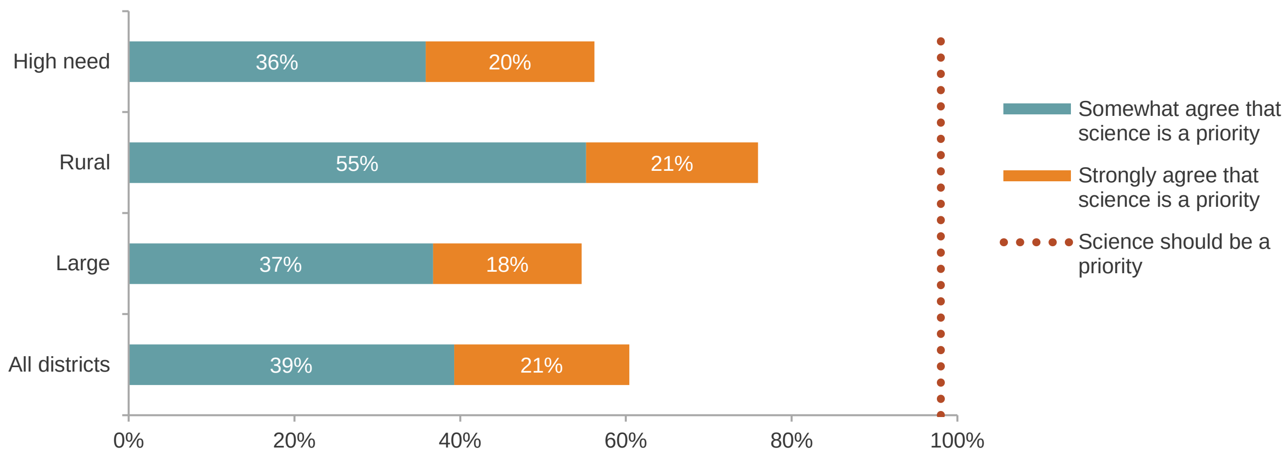
By many measures, science education has long taken a back seat to mathematics and English language arts. According to national statistics, in a typical week, 3rd-graders in public and private schools spend 8 to 10 hours on English and 5 to 6 hours on mathematics, but only 3 hours on science. The amount of time on science increases for 8th graders (4 hours) but it still lags behind English/mathematics (National Center for Education Statistics 2011). Parents in the United States do not think science is as important to their children's education or career prospects as reading, writing, or math (Overdeck Family Foundation 2017). However, three in five teachers nationwide feel that not enough emphasis is placed on science education (Bayer 2015).

In our survey, only 60 percent of districts reported that science *is* a priority in their districts; the share holding this view is lower among large and high-need districts (Figure 12). Recent accountability policies such as the federal Every Student Succeeds Act (2015) and its predecessor, No Child Left Behind (2001), have focused on closing the achievement gap in mathematics and English; and student performance on state standardized science assessments (in the 5th, 8th, and selected high school grades) are not used for accountability purposes (US Department of Education 2001, 2015).

In California, the new accountability system does not weigh science equally with mathematics and English. NGSS implementation is included as part of the implementation of state standards, but the state's academic indicator includes student performance only on Smarter Balanced mathematics and English. State and federal accountability criteria do not automatically improve student outcomes, but the absence of science proficiency from accountability measures may push the subject out of many classrooms, as schools and districts focus on high-stakes subjects such as mathematics and English (Marx and Harris 2006). This is particularly concerning because districts are implementing the Common Core State Standards in tandem with NGSS.

FIGURE 12

Rural and small districts are more likely to make science a priority



SOURCES: District response: PPIC NGSS survey, 2017. District enrollment size: California Department of Education, 2016–17. District geographic location: National Center for Education Statistics, 2013– 14. High-need student share: California Department of Education, 2016–17.

NOTES: Sample includes weighted responses from 204 school districts. Numbers do not add up to 100 because of the omission of "somewhat disagree", and "strongly disagree". We perform an ordered logit regression that includes district enrollment, geographic location, high-need students share, student performance, and district type. We report subgroup results only if the group indicator (rural, high need, large) is significant (see Technical Appendix B).

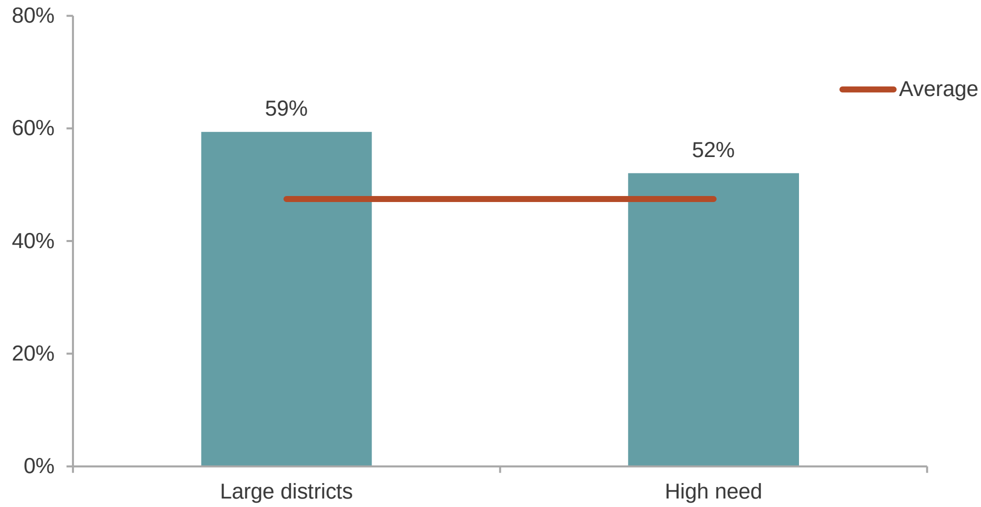
Investing in Early Science Education

Early exposure and encouragement is very important to science achievement in later years (Maltese and Tai 2010, Tai et al. 2006). However, there is mounting evidence that very few K–5 students have access to high-quality science education in US schools (Dorph et al. 2011; Trygstad et al. 2013). Concern about this lack of access is widespread among our survey respondents: 47 percent of unified and high school districts reported that limited exposure in early grades presents a big challenge in their districts, and the concern is more widespread among large and high-need districts (Figure 13). The level of concern is similar among elementary school districts, though the sample from our survey is very small (49).

The exposure problem has important equity implications. By grade 4, when the first NAEP science assessments are administered, African American, Latino, and low-income students are already behind their white and affluent counterparts. For instance, in California there is a 30 point gap between white and African American/Latino students, and a similar gap between affluent and low-income students (NAEP 2015). These early gaps persist and significantly affect student learning in later years (Morgan et al. 2016).

The good news is that NGSS present a unique opportunity to make science front and center in K–5 classrooms, since they fully integrate with the new mathematics and English language arts standards. Early evidence suggests some promising integration practices and more research is needed to understand its efficacy (Tyler et al. 2016, 2017).

FIGURE 13
Limited exposure to science in early grades is a big challenge in most districts



SOURCES: District response: PPIC NGSS survey, 2017. District enrollment size, high-needs student share, and district type: California Department of Education, 2016–17.

NOTES: Sample includes weighted responses from 204 school districts. We perform an ordered logit regression that includes district enrollment, geographic location, high-need student share, student performance, and district type. We report subgroup results only if the group indicator (e.g., high need, large) is significant (see Technical Appendix B).

Policy Recommendations

The Next Generation Science Standards provide new opportunities to improve science education in California. Districts have high hopes for NGSS, but most have experienced a variety of challenges as they implement the new standards in classrooms. To address these and other issues, we recommend the following to state leaders:

- The SBE should target outreach efforts to raise awareness in low-performance districts. The state has made significant progress in raising overall awareness, as 60 percent of district respondents are very familiar with the new standards. However, four years after the state adopted NGSS, close to a quarter of respondents in low-performance districts are only slightly familiar with the standards, which raises concerns about successful implementation in these areas. The state could also leverage county offices of education to raise awareness in these areas.
- The SBE and CDE should provide more clarification and guidance about the new science course sequence. The SBE adopted the integrated learning model as the preferred model for grades 6–8 and the discipline specific model as the alternative model. At the end of the 2016–17 school year, however, 20 to 30 percent of districts had not decided the course sequence for middle or high school grades. Findings from our survey can help districts learn from their peers; at the same time, more clarification and guidance from the state could help facilitate the process.
- The legislature should consider updating the high school graduation requirements to align with the new standards. The state's minimum course requirement includes two years of science (in biological and physical sciences), but a successful implementation of NGSS requires three years or more. In addition, the University of California (UC) and the California State University are considering expanding their science requirements from two years to three years to include disciplines that are identified by NGSS.

- State and local policymakers should consider adjusting other elements of the K–12 system to make science education a priority in schools, particularly in early grades. NGSS present a good opportunity, as the new standards are fully integrated with the state's new standards in mathematics and English language arts. State policymakers should consider altering the current accountability measure, which is focused on English and math, by incorporating the new science assessment. The purpose is not to punish or sanction schools, but to encourage districts to focus on science learning, including purchasing more science equipment and supplies, providing more professional development for science teachers, and devoting more instructional time to science in earlier grades.

NGSS is an important first step in redesigning and rethinking science education in California, however, it takes more than educational standards to transform student learning. More research is needed on the impact of instructional changes in classrooms and on students' science proficiency. Future work should also identify effective science pathways in both academic and career technical education, particularly for historically underrepresented students.

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