Chapter 12
Implementing High-Quality Science Instruction: Professional Learning, Leadership, and Supports

2016 Science Framework

FOR CALIFORNIA PUBLIC SCHOOLS
Kindergarten Through Grade Twelve

Adopted by the California State Board of Education
November 2016

Published by the California Department of Education
Sacramento, 2018

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Items in this document that relate to crosscutting concepts are highlighted in green and followed by the abbreviation CCC in brackets, **[CCC]**, with a number corresponding to the concept. The same items that correspond to the science and engineering practices are highlighted in blue and followed by the abbreviation SEP in brackets, **[SEP]**, with a number corresponding to the practice.

The Web links in this document have been replaced with links that redirect the reader to a California Department of Education (CDE) Web page containing the actual Web addresses and short descriptions. Here the reader can access the Web page referenced in the text. This approach allows CDE to ensure the links remain current.

Implementing High-Quality Science Instruction
Professional Learning, Leadership, and Supports

Introduction **1503**

Collaborative Systems of Learning and Support **1507**

Educators at the Core of the CA NGSS Implementation **1509**

From Professional Development to Professional Learning 1511

Professional Learning Throughout a Teacher's Career 1512

Teacher Preparation 1514

Induction for New Teachers 1515

Ongoing Professional Learning for In-Service Teachers. 1516

Characteristics of Effective Professional Learning 1516

Planning for Effective Professional Learning 1519

Strategies 1521

Examples of Effective Professional Learning Strategies 1522

Delivery Structures 1525

Teacher Leadership **1527**

Administrative Leadership and Professional Learning **1530**

Shared Leadership and Responsibility **1533**

Critical Issues 1534

Systemic Support for Professional Learning **1535**

Tools for Implementation 1535

Classroom Space and Equipment 1536

Programs and Partnerships to Support CA NGSS Learning 1538

Role of Parents, Guardians, and Families 1539

Community and Stakeholder Partnerships 1540

Types of Partners 1540

The Value of Effective Partnerships 1542

Examples of Partnerships in California 1543

Conclusion: An Ecosystem Approach **1545**

References **1546**

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Introduction

The California Next Generation Science Standards (CA NGSS) advance a new vision for teaching and learning **science and engineering practices (SEPs)**, **crosscutting concepts (CCCs)**, and **disciplinary core ideas (DCIs)**.

This presents a unique opportunity to transform science education in ways that will benefit all students and educators. Students will engage in science in deeper and more meaningful ways, they will ask more questions, and they will experience science through investigations. Teachers will focus on the big ideas of science and engineering and the practices they use, which will provide more opportunities for experimentation, design, and exploration.

The goal of this chapter is to provide recommendations (with examples and resources) to address the key shifts that must occur in several components of the education system to implement the CA NGSS effectively. These shifts should occur in coordination with each other. The chapter is not intended to be an exhaustive how-to manual with a checklist of items; rather the ideas and resources presented here are meant to meet various needs. It includes guidance to conduct further analysis of needs assessments and to research local contexts, as well as resources to develop a more targeted implementation plan.

The core message is that a change to only one component of the education system (for example, adoption of new curriculum materials) will not be sufficient to realize the vision of the CA NGSS. In particular, successful implementation of the CA NGSS will require that members of different educational institutions, communities, and systems establish new ways of working together with a focus on collaborative learning and growth for teachers, school leaders, and school systems as a whole that will enhance students' learning and academic success. This chapter provides guidelines for developing these new roles and relationships and develops perspectives on what is required to plan for, implement, and sustain the type of educational environment in which all students have the possibility to engage in the three dimensions of CA NGSS learning. Although changes are required for specific sections of the education system (from induction, to professional learning, to expanded and out-of-school learning opportunities), the CA NGSS provide a common vision that can guide this work to build vibrant classrooms and school cultures.

The California Department of Education (CDE) developed the *Mathematics Framework for California Public Schools: Kindergarten Through Grade Twelve (Mathematics Framework)* in 2013 and the *English Language Arts/English Language Development Framework for California Public Schools: Kindergarten Through Grade Twelve (ELA/ELD Framework)* in 2015. Research-based resources presented in this chapter overlap significantly with these two frameworks, but they have been further expanded to accommodate resources more specific to CA NGSS implementation. For example, recommendations from *Greatness by Design*, a 2012 report by the Task Force on Educator Excellence, call for changes in teacher education programs, increased mentoring for beginning teachers, centralization of teacher professional learning throughout teachers' careers, use of evaluation for teacher growth, and an expanded view of leadership pathways and opportunities for educators. The position of this framework is the same as that of the task force and it recognizes the importance of advocating for diverse organizations to work together within broad cultures of collaboration in support of teachers' growth. In addition, planning for successful implementation requires schools and districts to first assess existing education priorities, resources, systems, and professional knowledge and skills and then to develop district and school-level implementation plans that span multiple years.

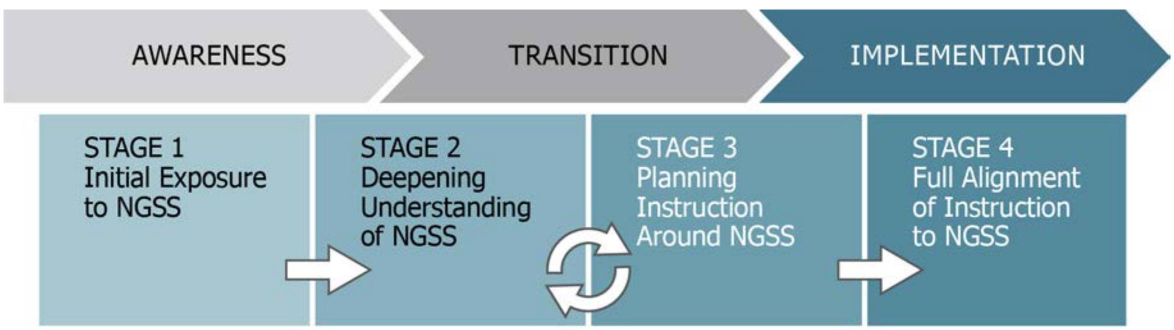
In response to the *Greatness by Design* report (Task Force on Educator Excellence 2012), the CDE convened a group of educators from across the state to guide the development of the Quality Professional Learning Standards (QPLS). Approved by State Superintendent of Public Instruction Tom Torlakson (SSPI) in December 2013, the QPLS identify a clear outcome for professional learning—to continuously develop educators' capacity to teach and lead so that all students learn and thrive—and seven interdependent professional learning standards that focus on the following:

- Data
- Content and pedagogy
- Equity
- Design and structure
- Collaboration and shared accountability
- Resources
- Alignment and coherence

By using the QPLS, educators, policymakers, education officials, and other stakeholders will share a common understanding regarding the features of high-quality professional learning and how best to support it. The standards are not meant to be used to evaluate educators in any aspect of their work. The QPLS are available on the CDE Web page at https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link1.

In addition to using the local education agencies' (LEAs') recommendations from the Implementation Plan for professional learning, districts might also find the CA NGSS Implementation Pathway Model (figures 12.1 and 12.2) helpful in thinking about planning for professional learning. This resource provides a visual model for changes in teacher understanding and practices that align with the state's phases of implementation. Of particular importance on figure 12.1 is the circular arrow between the stages of Deepening Understanding of CA NGSS and Planning Instruction around CA NGSS. These two stages are cyclical in nature. As teachers begin planning instruction aligned to the CA NGSS, they will need time and resources to deepen their personal understanding of the key instructional shifts of the CA NGSS laid out in the "Overview" chapter of this framework.

Figure 12.1. The CA NGSS Implementation Pathway Model



Long description of Figure 12.1.

In figure 12.2, the outcomes focus on implications for teaching and learning as teachers explore the key instructional shifts and the three dimensions of the CA NGSS, and begin planning instruction around bundles of performance expectations. To meet the outcomes in each stage of this model, teachers will need to dedicate significant effort toward their professional learning. Schools and districts will need to provide support and time for this learning to occur. It should be emphasized that all teachers in a school or district will not be at the same stage at any given time. Thus, there will be a need to differentiate professional learning for teachers in the coming months and years. In addition, the time needed to work through these stages should not be underestimated.

Figure 12.2. Stages in the CA NGSS Implementation Pathway Model

STAGE 1 **Initial Exposure to CA NGSS**	**STAGE 2** **Deepening Understanding of CA NGSS**	**STAGE 3** **Planning Instruction around CA NGSS**	**STAGE 4** **Full Alignment of Instruction to CA NGSS**
Teachers are beginning to learn and become familiar with the key instructional shifts, the three dimensions of learning, and the performance expectations of the CA NGSS.	Teachers engage in ongoing research and the building of personal understanding of the key instructional shifts, the three dimensions of learning, and the performance expectations of the CA NGSS.	Teachers begin planning lessons and units aligned to the three dimensions and performance expectations of the CA NGSS, returning to the previous stage as needed to ensure coherence with the key instructional shifts of the CA NGSS.	Teachers design and plan instruction aligned to CA NGSS curriculum and assessment.
Outcomes might include • describing the key instructional shifts of the CA NGSS and discuss implications for teaching and learning; • identifying the three dimensions of the CA NGSS; • explaining the anatomy and architecture of a CA NGSS standard; • identifying CA NGSS resources for further study and information	**Outcomes might include** • expressing how teaching and learning look in the CA NGSS for any standard and identifying each of the dimensions connected to the performance expectation; • describing what a science and engineering practice and crosscutting concept would look like in their classroom and providing examples of how they might engage students in these dimensions; • for a performance expectation, identifying a possible performance task that would assess student learning around the performance expectation.	**Outcomes might include** • reviewing grade-level or subject area performance expectations; • taking a current lesson/unit and translating it to the CA NGSS; • using the BSCS 5E instructional model or similar model to plan a learning cycle that integrates the three dimensions of the CA NGSS; • identifying and describing a performance task that could be used in the classroom to assess student performance and understanding around a performance expectation or multiple performance expectations.	**Outcomes might include** • implementing formative and summative assessments aligned to CA NGSS; • creating curriculum maps or implementing district curriculum guides; • implementing CA NGSS-adopted curriculum that is aligned to AIM, EQuiP, or similar rubrics.

Source: Spiegel, Quan, and Shimojyo 2014

In the final analysis, professional learning should serve as an umbrella that helps bring together the district's and school's plans for curriculum, instruction, and assessment. Districts need to consider short- and long-term plans for professional learning that work at the school site, as well as the district level, and connect to regional support (e.g., county offices of education, California Science Project, California Science Teachers Association, K–12 Alliance/WestEd). This plan needs to be supported with resources (time, money, expertise, and energy).

Collaborative Systems of Learning and Support

> *Implementing the NGSS will demand significant changes for everyone in schools and districts, from students to teachers to school and district leaders. All too often, though, we forget that implementing new standards requires purposeful design of learning opportunities for everyone in the system to develop an understanding of the standards and knowledge of the changes that will be required for curriculum, assessment, and professional development.*
>
> — William Penuel, Christopher Harris, and Angela Haydel Debarger, "Implementing the Next Generation Science Standards"

The CA NGSS were created by representative groups of teachers, administrators, parents, guardians, families, content experts, industry, support providers, and education professionals, each bringing a unique educational perspective into the development process. In continuation of this collaborative effort, it is essential that each stakeholder group play a vital role in the implementation plan to ensure the desired changes are both successful and sustainable and that they provide all students with meaningful access to learning opportunities centered on the CA NGSS. For implementation of the CA NGSS to be successful, it will take members of all of these groups working with educators and students to achieve the common goals. More specifically, effective planning and implementation of science instruction aligned to the vision of the CA NGSS require the targeted coordination of multiple systems of support represented by these diverse California stakeholders:

- Teachers, teacher librarians, and teacher leaders prepared to engage in student-centered teaching that engages students in three-dimensional science learning
- School, district, and county office administrators who are knowledgeable and supportive of the changes demanded by the CA NGSS
- Afterschool, early childhood, and other expanded learning opportunities aligned with and supportive of *three-dimensional science learning* that include collaborative and coherent efforts between teachers and other education support professionals
- College and university faculty involved in and advocates for high-quality science instruction and preparation of future teachers
- Community members and parents, guardians, and families who understand the reasons for and are supportive of the changed approaches to science teaching and learning

- Formal and informal learning environments, including museums, libraries, science centers and other venues that are fully committed to supporting CA NGSS

Effective progress takes place within these communities when it is aligned with an ongoing cycle of implementation, reflection, and improvement of practice (Little 2006; Penuel, Harris, and Debarger 2014; Fixsen et al. 2005; Fixsen and Blase 2009). The goal of this vision is for teachers and other educational stakeholders to engage in a learning culture that has the same characteristics—respect, intellectual engagement, and motivation toward continuous improvement—that we hope to create for our students in the classroom as the CA NGSS are being implemented.

Emerling and Gallimore (2013) present implementation models embedded in school learning communities across 40 districts. The focus is on addressing learning needs common to the members of the community; analysis of evidence is used to drive planning, decision-making, and critical questioning of practices. The context in which the learning community operates is embedded in a system of collaboration and trust among teachers and school leaders, all of whom recognize that change requires time, resources, continuous support, and an appreciation of risk-taking as new instructional approaches are implemented.

Therefore, the new education context for science instruction and learning should focus on the sustainability of the new instructional practices and education programs by fostering a collaborative school culture that engages educators, students, parents, guardians, families, education professionals, and community members (Fixsen and Blase 2009). This process allows all stakeholders to position themselves as advocates and supporters throughout all phases of the CA NGSS implementation.

The Next Generation Science Standards Systems Implementation Plan for California (CDE 2014) articulates specific guidelines that diverse stakeholders can use to coordinate and support their implementation efforts (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link2).

Finally, the *ELA/ELD Framework* states that teachers and educational leaders in schools and districts with culturally, linguistically, and otherwise diverse populations will need to examine their beliefs and attitudes toward students and their families. This is also true for the implementation of the CA NGSS. This explicit reflection ensures that educators approach all students with a positive disposition that both values the cultural resources and linguistic assets students bring to the science classroom and supports them to use their resources while expanding and adding new perspectives and ways of appropriating and using scientific language (Lee and Buxton 2010; Lemke 1990).

Educators at the Core of the CA NGSS Implementation

The confluence of three educational movements—the California Common Core State Standards (CA CCSS), the CA NGSS, and 21st Century Skills—provides a unique and unparalleled opportunity for student learning. The instructional shifts required by these movements, from knowing to sense-making, set the bar high for student learning and even higher for our schools. Teachers and administrators will not only have to consider a new context and programs, but they will need to think differently about their roles and their day-to-day work. The entire educational system will need to consider how to support these shifts throughout teacher and administrator careers (from pre-service to in-service) and how to implement policies and programs to support the transition from the awareness phase of the CA NGSS through and beyond the full implementation phase of the CA NGSS.

The critical need for investment in teacher and administrator learning has been made clear in efforts aimed at educational change. In the final analysis, there are no policies that can improve schools if the individuals in them are not armed with the knowledge and skills they need (Task Force on Educator Excellence 2012). Thus, this section builds on the findings of the Task Force on Educator Excellence report *Greatness by Design* and provides guidance on how to implement changes to current educational practices to meet the vision of the CA NGSS.

Given the critical value of teacher knowledge of both subject-matter content and pedagogical content (the most effective ways to teach students a specific subject), one would assume that continuous professional learning would be paramount in our educational system to promote student proficiency. Yet, the professional learning opportunities for science teachers have severely diminished over the past 10 years and are nonexistent in many schools. Dorph and her colleagues (Dorph et al. 2011), in a study of elementary teachers in California, found that only about a third of teachers surveyed felt very prepared to teach science, and more than 85 percent had not received any science-related professional development in the past three years.

Likewise, more than half of California middle grades science teachers surveyed rated the lack of professional development opportunities as a major or moderate challenge for quality implementation (Hartry et al. 2012). Surveys conducted by the CDE have consistently shown that sufficient support and professional development for the use of technology is not available to many teachers (Task Force on Educator Excellence 2012). Teachers also need more clarity in defining the most effective way to teach engineering in K–12 classrooms (National Research Council [NRC] 2009).

Current professional learning opportunities for principals are also limited. According to

Greatness by Design, "California principals reported being much less likely than those in other states to have participated in an administrative internship, to have access to mentoring or coaching, to have access to a principal's network while on the job, or to have participated regularly with teachers in professional development—a practice associated with effective instructional leadership" (Task Force on Educator Excellence 2012).

This paradigm must change. To meet the more rigorous expectations embodied in the CA NGSS, science teachers will need to teach in ways that are distinctly different than how most have been teaching; administrators will need to evaluate teachers and support programs in ways that are distinctly different than how most have been working as instructional leaders. Together, teachers, administrators, parents, guardians, and communities will need to form partnerships and collaborations to help all students reach their highest potential. To that end, the LEAs and schools need to provide sustained, coherent, high-quality professional learning experiences to teachers, administrators, parents, guardians, early childhood and expanded-learning professionals, families, and community members that result in enlightened learning environments for all students.

This section is organized into five sub-sections identifying the key components that allow the creation of a coherent and continuous pathway for teachers to learn and shift their instructional practices to meet the implementation demands of the CA NGSS:

1. **From Professional Development to Professional Learning** provides background information about the movement toward professional learning as a way to describe the types of learning experiences for educators engaged in continuous improvement.
2. **Professional Learning Throughout a Teacher's Career** addresses educators involved in providing pre-service education, district personnel involved in induction programs, and teachers and district personnel involved in in-service professional learning. The in-service portion of this section provides information on the elements of effective professional learning for the CA NGSS, strategic planning for professional learning, and examples of effective professional learning strategies.
3. **Teacher Leadership** suggests ways to build district capacity through teacher leadership.
4. **Administrator Professional Learning and Leadership** addresses both site and district administrators and describes the importance of administrators understanding the skills and knowledge of the CA NGSS to support the quality implementation of the standards.
5. **Systemic Support for Professional Learning** argues the need for quality support (time, effort, funding, personnel, stakeholders) throughout the awareness, transition, and implementation phases for CA NGSS and beyond.

Implementation of the CA NGSS requires building a coherent pathway for educators in which they are provided with learning environments that promote risk-taking/critical thinking and resources (time, funding, and support) to reflect and improve on their instructional and administrative practices.

From Professional Development to Professional Learning

> *It is clearer today than ever that educators need to learn, and that's why professional learning has replaced professional development. Developing is not enough. Educators must be knowledgeable and wise . . . They must become learners, and they must be self-developing.*
>
> —Lois Brown Easton, "From Professional Development to Professional Learning"

The shifts demanded by CA NGSS for teachers, administrators, and their support community require a change in the way we think about professional development, staff development, and training. The current fragmented menu of short, discrete professional development offerings does not support the need for continuous collaboration required to implement CA NGSS. Similarly, the one-shot workshops, or "sit 'n get" sessions, do not embrace the characteristics of effective professional learning necessary to achieve a deeper understanding of CA NGSS.

The research-based characteristics of effective professional development suggest a vision of teacher learning opportunities that are better described as professional learning. *Professional learning* refers to planned and organized processes that actively engage educators in cycles of continuous improvement guided by the use of data and active inquiry around authentic problems and instructional practices (Coggshall 2012).

The following table 12.1, adapted from the National Comprehensive Center for Teacher Quality's publication *Toward the Effective Teaching of New College- and Career-Ready Standards: Making Professional Learning Systemic*, summarizes key shifts for science professional learning that distinguishes it from professional development.

Table 12.1. Key Shifts for Science Professional Learning

MOVING FROM	MOVING TOWARD
Believing that professional development is some people's responsibility	Believing that professional learning focused on student learning outcomes is everyone's job
Thinking individual goals for professional development are separate from school site and district goals	Aligning individual goals with school site and district goals to provide greater coherence
Using professional development as a means of addressing deficiencies	Embedding professional learning in continuous improvement
Seldom addressing standards for professional learning	Using standards for professional learning
Providing professional development that takes place outside of school, away from students, and is loosely connected to classroom practice	Embedding professional learning in daily work so that staff can learn collaboratively and can support one another as they address real problems and instructional practices of their classrooms
Engaging staff in professional development unrelated to data and the continuous improvement process	Engaging staff in a cycle of continuous improvement, guided by the use of multiple data sets and active inquiry
Providing one-shot or short–term professional development with little or no transfer to the classroom	Sustaining continuous professional learning through follow-up, feedback, and reflection to support implementation in the classroom
Limiting professional development based on scarce resources and discrete funding sources	Dedicating and reallocating resources to support professional learning as an essential investment

Source: Coggshall 2012

The shifts listed in table 12.1 guide the assumptions and recommendations found in this chapter. Professional learning needs to be "center-stage" throughout the implementation of the CA NGSS.

Professional Learning Throughout a Teacher's Career

Much has been learned in the last several years about effective science instruction, including the importance of paying attention to student thinking throughout instruction, providing opportunities for all students to delve deeply into substantive scientific ideas, and metacognition (NRC 2000 and 2005). Similarly, the field has gained considerable knowledge about effective professional learning experiences that provide teachers with opportunities to reflect on their practice and to deepen their understanding of science and how students learn science. To realize the potential of the CA NGSS, it will be critical to invest in professional learning for teachers of science as well as for those who play an important role in shaping what happens in classrooms (Banilower, Gess-Newsome, and Tippins 2014). To support a three-dimensional learning environment in their classrooms, teachers must experience the value of such an environment in their own learning experiences.

This section discusses strategies and provides suggestions to support teachers at every stage of their career (pre-service, induction, in-service) with the knowledge, skills, and dispositions necessary for effective teaching of the CA NGSS. Essential to this support is the development of a learning community embedded in a system of collaboration and trust among institutions, teachers, and school leaders. Members of the community recognize that the change process requires time, resources, continuous support, and an appreciation of risk-taking as new instructional approaches are implemented.

Looking at teacher professional learning as the first step is important because teacher quality is one of the most important influences in student achievement and learning (Darling-Hammond 2005). Key to the implementation of high-quality science programs is having teachers who have deep content-area knowledge (Floden and Meniketti 2006, 261–308; Rice 2003; Wayne and Youngs 2003) and enhanced pedagogical skills (Rice 2003; Allen 2003; Boyd et al. 2005). Pedagogical content knowledge (Shulman 1986), or the skills and knowledge of how best to facilitate student learning of specific content, is of particular importance in helping students experience the three-dimensional learning process represented in the CA NGSS. Therefore, it is necessary for teachers to understand how children think and learn, how to differentiate instruction to fit students' needs, and how to assess learning continuously to diagnose students' progress toward deeper understanding (Darling-Hammond and Bransford 2005).

Given these factors, the expertise needed to implement the CA NGSS requires articulated professional learning experiences throughout the teacher career continuum from pre-service and induction to in-service. Linking these phases in a teacher's career provides a context for continuous professional growth that can result in teachers' practices that engage students in three-dimensional learning.

The emphasis on building students' understanding of the core ideas, practices, and crosscutting concepts over multiple grade levels implies that "teachers will need to appreciate both the current intellectual capabilities of their students and their developmental trajectories.

Toward this end, [all] teachers will need experiences that help them understand how students think, what they are capable of doing, and what they might reasonably be expected to do under supportive instructional conditions" (NRC 2012, chapter 11). In the context of newer science and engineering practices, such as computational thinking, teachers are best able to understand how students think by engaging in the practices themselves and reflecting on their own learning experiences prior to integrating the practices into their classrooms.

Teacher Preparation

> *It is essential that all educators are well prepared and well supported in order to have a stable, diverse, high-quality educator workforce that serves all of California's culturally and linguistically diverse students from preschool through high school in every community.*
>
> — Task Force on Educator Excellence, *Greatness by Design*

As the CA NGSS are implemented across California, the phases of new teacher preparation and induction are key factors in providing a pipeline of teachers with the skills and knowledge to provide high-quality CA NGSS-aligned instruction. Educators of pre-service teachers need to adjust their programs to reflect the three-dimensional learning vision of the CA NGSS so that pre-service teachers have the opportunity to experience it as learners. Factors to consider in the development of CA NGSS-aligned teacher preparation programs include

- student teaching opportunities that include content-rich experiences and integrated learning experiences (particularly to those interested in the middle grades);
- science and science methods classes that address three-dimensional learning with emphasis on learning disciplinary ideas through the science and engineering practices and crosscutting concepts rather than lecturing;
- science methods classes that address pedagogical content knowledge that facilitates student conceptual understanding of DCIs over time and how to address incorrect and alternative student conceptions of those ideas;
- science methods classes that address and student teaching experiences that focus on the nature of science;
- student teaching experiences with science teachers who are effectively incorporating CA NGSS;
- student teaching experiences that accurately reflect the integration of the CA NGSS with the CA CCSS;

- effective examples of how engineering integrates into the science curriculum to enhance understanding in all three dimensions of the CA NGSS (in both pre-service teachers' course work and student teaching);
- science methods classes that address how to organize science instruction, including how to 1) bundle performance expectations together to establish goals for units; 2) identify appropriate phenomena that will engage students in the three dimensions; and 3) sequence instruction using effective principles of lesson design such as the 5E model of instruction.

Additionally, science education faculty and other educators (e.g., university field advisors, master cooperating teachers) who provide pre-service instruction must be grounded in the knowledge and skills within the context of CA NGSS to facilitate their students' (pre-service teachers) ability to address the vision in the CA NGSS. The Pre-service Experiences section in chapter 10 of the *NRC Framework* provides valuable strategies aligned with CA NGSS for science education faculty to start thinking about the implications for reforms required in the teacher preparation programs. Other publications, *Preparing Teachers—Building Evidence for Sound Policy* (NRC 2010a), *Powerful Teacher Education, Lessons from Exemplary Programs* (Darling-Hammond 2006), and *Exemplary Science for Building Interest in STEM Careers* (Yager 2012), are also important resources for guiding the design of high-quality teacher preparation programs.

Induction for New Teachers

Teaching is hard and thoughtful work. New teachers often feel isolated and burdened by the demands (both managerial and instructional) of working in a classroom. Yet, this situation can be alleviated to a large degree by the implementation of effective preparation and support programs specifically tailored to the needs of new teachers:

- As part of the teacher induction process, pair beginning science teachers with experienced science teachers to act as mentors rather than delegating induction efforts only to general teacher induction specialists or programs. This connection may help address the need for inclusion and may provide a sense of ownership to the content and science department, leading to greater teacher retention.
- Recognize and support the need for elementary teachers to receive science-specific support and mentoring on the same level as that provided for mathematics and language arts.
- Ensure that beginning science teachers have *comparable access* to science teaching resources and *teaching space* for hands-on instruction as other science teachers in their school.

- Involve new teachers in available Professional Learning Communities or the like, particularly science-specific ones, in order to promote and aid regular reflection on their practice (Fulton, Britton, and Doerr 2010).
- Encourage new teachers to attend science teacher conferences, institutes, and workshops (and financially support them to do so).

Ongoing Professional Learning for In-Service Teachers

This section addresses the professional learning that is necessary for in-service teachers and the ongoing support they require to implement the CA NGSS. This section incorporates recommendations from *Greatness by Design* (Task Force on Educator Excellence 2012) and *Innovate: A Blueprint for Science, Technology, Engineering, and Mathematics in California Public Education* (STEM Task Force 2014). This section also discusses components of effective professional learning plans from a variety of sources, in particular Loucks-Horsley's *Professional Development Design Framework* (Loucks-Horsley et al. 2010) as a planning tool for districts and other research-based literature. Lastly, this narrative resonates with the professional learning recommendations made in both the *ELA/ELD Framework* (CDE 2015) and *Mathematics Framework* (CDE 2013).

Characteristics of Effective Professional Learning

Research has shown that certain characteristics of professional learning are more effective than others in changing teacher knowledge and effectiveness. As the Task Force on Educator Excellence notes in *Greatness by Design*, "Professional learning can have a powerful effect on teacher skills and knowledge and on student learning. To be effective, however, it must be sustained, focused on important content, and embedded in the work of collaborative professional learning teams that support ongoing improvements in teachers' practice and student achievement" (2012, 50).These findings are of particular importance for quality implementation of the CA NGSS.

In particular, Reiser (2013) suggests four areas that make professional learning effective for supporting science instruction and learning that is subject-matter centered, uses active learning, is connected to teacher practice, and is coherent.

1. **Subject-matter centered:** Professional learning should be deeply connected to up-to-date-subject matter (Garet et al. 2001; Wei, Darling-Hammond, and Adamson 2010). Teachers require a basic level of knowledge and skills with subject knowledge deep enough and instructional methods broad enough to deliver a high-quality curriculum to each student (National Board for Professional Teaching Standards 2007;

Wilson 2011). In the case of the CA NGSS, this means that instructional practices must be connected to the three dimensions of the CA NGSS (science and engineering practices [SEPs], disciplinary core ideas [DCIs], and crosscutting concepts [CCCs]) and emphasize the specific content at the teacher's grade level and the connection of that content to other grades. For example, teachers must shift from teaching procedures and rules to facilitating student reasoning around DCIs, SEPs, and CCCs and from having students memorize facts to engaging them in critical thinking around the three dimensions of the CA NGSS. Professional learning needs to help teachers deeply understand teaching of the DCIs through the SEPs and CCCs, which are discussed in detail in the "Instructional Strategies" chapter of this framework.

2. **Active learning:** Professional learning needs to involve active sense-making and problem solving (Garet et al. 2001). The environment for teacher learning needs to model what is expected to occur in classrooms. If the expectation is for teachers to help students develop their meaning making and ability to solve problems, then teachers need experiences in which they analyze cases, deconstruct examples of students' reasoning, and reflect on their own teaching practices to figure out what can be applied to their teaching context. There are several effective strategies for this: (a) classroom observation or videos to help teachers analyze classroom practice, for example, student-to-student discourse; use of phenomena to raise questions; student construction of explanations of target ideas; (b) lesson study focused on the effectiveness of the lesson design on student learning; and (c) analyzing and interpreting student work that represents student thinking, for example, analysis of student notebooks from their prior knowledge of a target idea to their explanation of their current understanding. Active learning includes both individual and collaborative reflection (Desimone et al. 2002; DiRanna et al. 2008) in which teachers analyze their thinking, share with others, and have multiple opportunities for feedback and discussion.
3. **Connected to Teacher Practice:** Professional learning should connect deeply to teachers' practice. Since the 1990s, researchers (e.g., Ball and Cohen 1996; Darling-Hammond 1995) have continued to underscore the importance of providing teachers sufficient opportunities and support to apply changes in their own classroom practice. Teachers need to "learn in, from, and for practice" (Lampert 2009). Strengthening teacher content knowledge is important but not sufficient for teachers to translate what they have learned into their classrooms (Heller et al. 2012). Heller's research found that "integrating content learning with analysis of student learning and

teaching was more effective than advanced content or teacher metacognition alone."

By connecting professional learning to teacher practice, teachers can focus on transformative changes (Thompson and Zueli 1999, 341–375). Using high-leverage practices is instrumental in initiating change in teacher pedagogy (Ball et al. 2009; Smith and Stein 2011; Windschitl et al. 2012). For example, model-based and evidence-based argument represents "dramatic divergences from common science teaching practice, and thus are key in helping teachers make the shift to a pedagogy aligned with . . . the [CA] NGSS" (Reiser 2013).

Changes in teacher practice must also include constructing collaborative learning environments in which teachers work together to understand, apply, and reflect on the reforms (Garet et al. 2001; Wilson 2013). Working together, teachers can debate their interpretations of standards-aligned teaching, collectively make meaning, and reach consensus. They focus on authentic problems by doing the science, analyzing student work and analyzing how teaching facilitates learning (Darling-Hammond 1997).

4. **Coherence:** Professional learning needs to be part of a coherent system of support. The adoption of the CA NGSS and the CA CCSS requires that professional learning be front and center to drive quality implementation of the standards. Connecting professional learning to classroom practice requires that teachers explore what a coherent system—composed of student learning, classroom teaching, assessment, and curriculum materials—needs in order to succeed; and they must work on making changes across the corresponding parts of that coherent system (Reiser 2013).

In addition to the four characteristics addressed by Reiser (2013) and described above, research indicates that the overall duration and collective participation in a community of practice are important components of effective professional learning. Long-term professional learning experiences with feedback loops and follow-up are most effective. Some researchers indicate that professional learning lasting less than 80 hours is not fully effective to achieve significant and sustained changes in classroom teaching practices (Supovitz and Turner 2000; Banilower, Heck, and Weiss 2007). Not only is the total amount of time devoted to professional learning important, so is the *flow* of the professional learning. The span of time and the frequency over which the professional learning occurs are important factors to consider. For example, job-embedded professional learning (e.g., lesson study or analyzing current student work) that is based in the context of the teachers' classroom has been shown to be particularly useful (Fogarty and Pete 2009; Lewis 2008).

Collective participation in a community of practice (e.g., teachers within the same grade level, from the same school or department) is another important characteristic that makes professional learning effective in transforming and sustaining teachers' instructional shifts. This type of participation builds school culture, establishes norms of trust, and provides structure for the learning being part of "what we do" (National Institute for Excellence in Teaching 2012). For all students to succeed in the CA NGSS, teachers will need to think across grade levels, building on students' foundations of conceptual understanding. While the CA NGSS learning progressions help with the vision of this articulation, collective participation by school staff is more likely to result in implementing the vision. See more about communities of practice in examples of professional learning strategies.

Planning for Effective Professional Learning

The key instructional shifts required by the CA NGSS call for a more effective system of professional learning. Teachers, specialists, paraprofessionals, and school and district leaders need to identify personal and collaborative learning goals that articulate across grade levels and departments, focusing on curriculum, instruction, and assessment strategies that embrace the vision of the CA NGSS. The school, district, and other LEAs must become "learning organizations" (Senge 1990) that are engaged in continuous improvement around the implementation of the CA NGSS. At every level (grade level, department, school, district) educators must see the implementation of CA NGSS as a professional learning community with a shared vision that focuses on student learning, collaboration, collective inquiry, shared practices, reflection, and results (Louis, Kruse, and Marks 1996, 179–203; DuFour 2004; Hord and Sommers 2008).

County offices of education, districts, schools, and professional learning providers can use the *Designing Professional Development for Teachers of Science and Mathematics* (Loucks-Horsley et al. 2010) as a resource for planning these types of learning experiences. This book places the design of professional learning firmly within the context of standards-based reform and a performance-based culture that seeks to continuously improve professional practice and student achievement (ix).

Through their research with outstanding national professional developers, Loucks-Horsley and her colleagues (2010) found that there were no effective *models* of professional learning. Instead, they discovered that effective programs had several common characteristics. They were designed to meet various factors, to change over time, and to adapt to particular goals and contexts. There were no formulas; instead, the designers used a process of thoughtful, conscious decision making. The authors used these factors and processes to create the Professional Development Design Framework as seen in figure 12.3 below.

Figure 12.3. Professional Development Design Framework

Source: Loucks-Horsley et al. 2010
Long description of Figure 12.3.

At the center of the design framework, illustrated in the six squares connected with horizontal arrows, is a planning sequence that includes the following topics: (1) committing to a vision and a set of standards; (2) analyzing student learning and other data; (3) goal setting; (4) planning; (5) doing; and (6) evaluating. The circles above and below the planning sequence represent important *inputs* into the design process that can help designers of professional learning make informed decisions. These inputs prompt designers to consider the extensive knowledge bases that can inform their work (knowledge and beliefs), to understand the unique features of their context, to draw on a wide repertoire of professional development strategies, and to wrestle with critical issues that science education reformers will encounter.

While there is no exact starting place in using the design illustrated in figure 12.3, there is a major caution to *not* start with strategies even though those are often most appealing. Instead, the use of data (what are the assets, what are the needs) is encouraged. Additional considerations should be made, such as thinking about short- and long-term approaches (up to five years), considering teacher career trajectories, and supporting teachers accordingly (Task Force on Educator Excellence 2012). Planning broadly for the awareness, transition, and full implementation phases of the CA NGSS is also a recommendation. However, developers of professional learning must also be mindful of the need to be flexible and adaptive, and they must be willing to refine their ideas as the implementation process is being evaluated. As the design and implementation phases are taking place, recommendations from *Innovate: A Blueprint for Science, Technology, Engineering, and*

Mathematics in California Public Education (STEM Task Force 2014) and characteristics of effective professional learning should also be considered during the design phase.

A note of caution: while the professional development design framework in figure 12.3 looks linear and sequential, it really is not. What is most important is to pay attention to the four core design inputs, where they impact the design of the program, and how they are addressed as implementation occurs.

Strategies

Strategies refer to proven methods for professional learning. These experiences are robust, consistent with the principles of effective professional learning, and meet the requirements for transformative learning experiences (Thompson and Zeuli 1999, 355–357). Effective strategies for implementation of the CA NGSS range from meeting awareness needs to meeting implementation needs as districts and schools move toward full implementation. Consider multiple learning experiences for teachers to build their content and pedagogical content knowledge and examine their practices. The learning experiences should create high levels of cognitive dissonance to cause teachers to reflect on their current beliefs/practices versus new information about the CA NGSS and then provide time and support for the teachers to think through the dissonance they experience.

Following the recommendations of *Innovate: A Blueprint for Science, Technology, Engineering, and Mathematics in California Public Education* (STEM Task Force 2014), districts can take the following steps:

1. Participate in statewide professional learning networks (e.g., California Science Project [CSP], California Science Teachers Association [CSTA], K–12 Alliance/WestEd).
2. Participate in the professional learning offerings of local science organizations (e.g., county offices of education and informal science sites such as zoos, aquariums, museums, and field-based environmental education experiences).
3. Coordinate with expanded learning programs (e.g., after-school programs) or early childhood programs (e.g., preschool) to offer articulated professional learning for all teachers that span the grade bands. For example, the after-school robotics program might coordinate with the regular school-day program.
4. Plan for leadership training for teachers and administrators. Leadership is key to sustaining professional learning for districts and schools (see the section on teacher and administrator leadership). The plan must include strategic opportunities for teachers and administrators to be supported and fostered as leaders.

5. Although not included in *Innovate*, districts can also encourage teachers to take additional course work in their content area, with an emphasis on courses that involve the teachers in active learning.

Examples of Effective Professional Learning Strategies

In this section, several types of strategies and delivery structures are discussed. There are three essential "take-away" messages for selecting professional learning strategies beyond the obvious requirement that the strategies have to match the larger context and address effective characteristics of professional learning:

- First, one-size strategies do not fit all teacher learners.
- Second, multiple strategies and delivery structures are needed to meet the complex learning goals for the CA NGSS.
- And third, without long-term support in terms of policy, procedures, and resources (including time and fiscal resources), none of the strategies can be effective.

Many strategies for professional learning can be used; what is critical is that their selection be based on a comprehensive plan for professional learning coordinated at the district and school levels and informed by teachers and other staff (CDE 2015). With that in mind, Loucks-Horsley et al. (2010) suggest four categories of strategies that can be helpful in designing CA NGSS professional learning experiences:

1. **Immersion in Content, Standards, and Research.** The complexity of the CA NGSS demands that teachers, other staff, and administrators not only become aware of the standards, but that they deeply immerse themselves in them. This includes providing content knowledge background across K–12. Content knowledge, in addition to the disciplinary core ideas in life, Earth, and physical science and engineering, also includes knowledge of the science and engineering practices and the crosscutting concepts. Professional learning of modern scientific practices, such as computational thinking, modeling and simulation, can be gained at workshops offered by partners from industry and/or universities. Immersion might include enrolling in carefully chosen college classes, taking part in industry-related job shadowing or summer work-experience opportunities, or doing field studies with a college-level faculty advisor. As students are asked to grapple with the nexus of three-dimensional learning, teachers will also have to experience new types of learning that challenge old paradigms and help them internalize the vision of the CA NGSS (see "Overview" chapter). Strategies in this category need to be ongoing to provide refinement of

teachers' thinking as they implement the standards.

2. **Examining Teaching and Learning.** This is the crux of the implementation for the CA NGSS. The nuances of the standards, the changes in pedagogy to have students learn content through practices, and the assessments that will measure three-dimensional learning will require in-depth and long-term professional learning experiences. These experiences need to transform individual teacher practice as well as influence the teaching practices of their colleagues. Indeed, these professional learning experiences need to transform the school culture. Multiple strategies fit into this category: (1) analysis and interpretation of student work; (2) demonstration lessons by a peer, coach, or professional development provider; (3) lesson study during which a team of teachers designs, teaches, and analyzes the impact of the lesson design on student learning; (4) action research in which teachers investigate the effectiveness of something they care about (e.g., trying various instructional strategies to determine which has the greatest impact on student learning); (5) case discussions in which collaborative groups discuss important educational or instructional topics; (6) coaching; and (7) mentoring. Each of these strategies has protocols that are too complex to explain in this document, but all of them require analysis, reflection, and improvement based on data. An important addition to the list is developing an understanding of formative assessment as an instructional tool. As these types of strategies are considered, it is important to recognize that these strategies are most effective when delivered collaboratively by skilled facilitators. Once the appropriate strategies for a professional learning plan are determined, these strategies need to be supported with sufficient time and appropriate expertise and funding.
3. **Aligning and Implementing Curriculum.** It is a challenge to provide quality, in-depth professional learning experiences for every teacher. Often the instructional materials are the only tools teachers have to become better prepared to teach science. Thus, the selection of the instructional materials is extremely important to helping teachers understand and implement the CA NGSS. Instructional materials are also an opportunity to educate teachers and can provide a strong basis for teacher learning. Implementation of the instructional materials requires ongoing support, but this support is not a substitute for comprehensive professional learning. No instructional materials can address every classroom situation. Teachers must be able to understand student thinking and adapt materials or find other resources to improve understanding for all students. As strategies in this category are considered, instructional materials and ancillary resources should also be included to support

instruction. How might teachers learn how to use tools and processes to help organize student exploration? How can teachers (and administrators) learn to be critical consumers of instructional materials? How can teachers learn to use the Educators Evaluating the Quality of Instruction Products (EQuiP) rubric from Achieve to evaluate instructional units or lessons?

4. **Professional Collaborations.** Community and leadership cannot occur if teachers remain isolated from each other. Departments and schools should institute policies and procedures that support (1) teacher collaboration (within grade levels, across grade levels, as well as within a subject and across subjects); (2) risk taking; (3) collegiality with other teachers, including specialists for English learners and those supporting students with disabilities, as well as with experts outside of the school environment; and (4) teacher leadership opportunities within, and outside of, the school. Developing this community requires recognition that professional learning is a lifelong process that is best nurtured within the norms and culture of the school (Mundry and Stiles 2009, 5).

The creation of learning communities among professionals in different educational roles is one of the most effective vehicles for fostering learning while implementing the CA NGSS. These communities should include rather than exclude, create knowledge rather than merely apply it, and offer both challenges and opportunities as teachers and administrators become leaders and colleagues in this process.

As research on effective educational school reform continues to grow (Fullan 2001; Fixsen and Blase 2009), the social practices that operate within the school environment have the potential to foster and strengthen highly collaborative professional communities. Throughout the phases of implementation of the CA NGSS, teachers, principals, and other administrators must position themselves as learners and engage in collaborative work with colleagues to transform new classroom experiences into teaching expertise (Weinbaum and Supovitz 2010; Weinbaum et al. 2004).

Through these social practices, teachers and school leaders play the roles of both experts and learners, recognizing and building knowledge from practice and encouraging one another to continually seek better ways of reaching students. In *Teachers–Transforming Their World and Their Work*, Lieberman and Miller (1999) paint a clear picture of effective school collaboration in which individual classroom practices and organized school culture allow schools "to be places where children and adults can learn and thrive."

Professional Learning Communities (PLC) (DuFour 2004), a type of professional collaboration, incorporate a solid foundation consisting of collaboratively developed and widely shared mission, vision, values, and goals; cooperative teams that work interdependently to achieve common goals; and a focus on results as evidenced by a commitment to continuous improvement (Eaker, DuFour, and DuFour 2002). In a CA NGSS-aligned PLC, effective progress takes place in a way that is aligned with an ongoing cycle of implementation, reflection, and improvement of practice (Little 2006; Penuel, Harris, and Debarger 2014; Fixsen et al. 2005; Fixsen and Blase 2009). This stance puts forth a vision in which teachers and other educational stakeholders engage in a learning culture that reflects the same characteristics of respect, intellectual engagement, and motivation toward continuous improvement that we hope to create for our students in the classroom as the CA NGSS are being implemented. The context in which the learning community operates is embedded in a system of collaboration and trust among teachers and school leaders and engages parents, guardians, families, education professionals, and community members (Fixsen and Blase 2009). This process allows all stakeholders to position themselves as advocates and supporters throughout all phases of the CA NGSS implementation.

Creating these collegial structures in schools is crucial for successful implementation of the CA NGSS in combination with the CA CCSS for ELA/Literacy, the CA CCSSM, and the CA ELD Standards. Analyzing and finding integration opportunities requires that teachers be given the time to collaborate frequently and regularly to assess students' accomplishments, learning, and needs and plan for integrated and interdisciplinary instruction. These collaborative opportunities need to occur within grades, across grade spans within schools, and among elementary, middle, and high school programs.

Delivery Structures

Many structures can be used to deliver professional learning. Loucks-Horsley et al. (2010) suggest four: (1) study groups; (2) workshops, institutes, and seminars; (3) professional networks; and (4) online professional learning. Each of these structures allows a variety of specific strategies to be used within the structure, yet some structures are better than others for the goal of the learning. For example, if the goal is to increase teacher content knowledge for the CA NGSS, selecting a short-term workshop may not be the wisest choice, whereas a multiple-day institute might provide more opportunities for teachers, like their students, to use SEPs and CCCs to develop DCI understanding. Likewise, even with an appropriate structure for the initial learning, several overlapping structures might be needed to fully reach the intended outcome. In the case of the multiple-day institute, the end goal would be to teach using the new knowledge and skills in the classroom. In this case, coupling the institute with a study group of some kind (e.g., grade-level meeting, professional learning community) might bring about the desired results more readily and effectively.

When selecting delivery structures, coherence with existing school or district plans and structures as well as cultural norms at the school site must be considered. How will these delivery structures build on what already exists? What support do you need to develop or use these structures—for example, who can facilitate? What is the human capacity within the district or school? When might outside facilitators be required?

In terms of online professional development, the advantages and disadvantages for using this approach need to be assessed: What type of technology is necessary? What type of training is further necessary to optimally use the technology for this purpose? Who will monitor online conversation threads? Should the online component stand alone, or are there reasons for face-to-face sessions? Careful analysis of online resources for professional learning is required to match appropriate needs. *The Next Generation Science Standards Systems Implementation Plan for California* (CDE 2014a) calls for the expansion of CDE's Professional Learning Modules to include modules targeting the CA NGSS implementation.

In summary of the planning process for in-service professional learning, it is paramount to reflect on the Professional Development Design Framework components (knowledge and beliefs, context, critical issues, and strategies) to help focus on a specific vision and goals aligned with the local contexts and needs. The implementation plan must be strategic and thoughtful, and it should be collaboratively evaluated on a regular basis by teachers, administrators, parents, guardians and the community in light of the resulting professional-learning experiences. Professional learning providers and educators should revisit beliefs about teacher learning and continually check the choice of strategies against the changing context of the district to maximize the effectiveness of the plan. Core strategies should be kept as foundational, but planners should be open and flexible to meet the emerging needs of the educators. Finally, and most importantly, teachers, professional developers, and administrators should engage in their own cycle of continuous improvement and become a community of learners.

Teacher Leadership

Ultimately, developing and implementing effective professional learning for teachers takes expertise, which requires district capacity. The continued use of outside expertise can diminish the district's capacity to build internal leadership; conversely, using in-house personnel without the necessary expertise can hinder the CA NGSS learning experience. Districts must consider how to build teacher, curriculum, and administrative leadership, with the assistance of outside sources, to strengthen their long-term capacity to implement the CA NGSS. For this reason, leadership for professional learning should be shared among many individuals at the school and district levels. Every district will have some teachers who have stronger science backgrounds and are more active in seeking opportunities to develop their capacity to provide three-dimensional science learning opportunities. Identifying these "early adopters" and giving them both support for their own learning and leadership roles (by providing additional learning opportunities and networking opportunities outside of the district) in supporting other teachers to adapt their teaching to meet the demands of these new standards can be an effective way to strengthen a school or district's professional learning networks for science.

This section begins with teacher leadership as a core strategy for implementing the CA NGSS because research (Bybee 1993; Lieberman and Miller 2004; Weiss and Pasley 2009; Penuel, Harris, and Debarger 2014) indicates that leadership and support are required for professional learning experiences to be turned into changes in teaching and learning practices. Teacher leadership is associated with increased teacher learning and creating collaborative professional cultures (York-Barr and Duke 2004) as well as being positively related to increased student achievement (Waters, Marzano, and McNulty 2003).

Teacher leadership addressed in this section resonates with a definition of leadership from Julian Weissglass (1998): "Teacher leadership is about taking responsibility for what matters to you." In other words, teacher leaders include every teacher, those who are seeking or are designated teacher leaders, department chairs, teachers on special assignment, mentors and coaches, etc. In other words, everyone has the capacity for leadership, and one goal of science teacher leadership is to have many, rather than a few, people leading creatively every day and in all aspects of their lives (Kaser et al. 2002). This view of teacher leadership differs from the traditional view in that leadership is not about power and authority. Instead, it embraces five practices of exemplary leaders (Kouzes and Posner 2001) as listed in table 12.2.

Table 12.2. Practices of Exemplary Leadership

PRACTICES OF EXEMPLARY LEADERS	DESCRIPTOR
Challenging the process	Searching for opportunities to change the status quo and innovative ways to improve
Inspiring a shared vision	Seeing the future and helping others create an ideal image of what the organization can become
Enabling others to act	Fostering collaboration and actively involving others
Modeling the way	Creating standards of excellence and leading by example
Encouraging the heart	Recognizing the many contributions that individuals make, sharing in the reward of their efforts, and celebrating accomplishments

Leadership development is not as simple as creating better classroom teachers; it requires explicit attention, clear expectations, and resources (time and expertise) (Friel and Bright 1997). Science teacher leaders need to possess (1) an in-depth knowledge of the science in the CA NGSS; (2) thorough knowledge of the best practices in teaching and learning aligned to the three-dimensionality of the CA NGSS; (3) an understanding of school culture, organization, and politics; (4) an understanding of change theory; (5) knowledge of how adults learn; and (6) practices that embrace continuous improvement. Additionally, leaders need skills in facilitation and communication, using data and decision making, and organization, to name a few.

Teacher leaders can take on a variety of roles to help colleagues and other educators, as well as parents, guardians, and community members become more aware of the shifts required by the CA NGSS and to deepen teacher practices to align with the CA NGSS. These roles include leading in the areas of (1) instruction and assessment with particular attention to the nexus of the three dimensions; (2) curriculum and instructional materials with particular attention to access and equity for all students; (3) school culture that is supportive and proactive for the implementation of the CA NGSS; (4) community support and advocacy for science as a core subject; and, (5) science teacher implementation of the Common Core literacy standards.

To develop these knowledge and skill sets, teacher leaders need professional learning targeted toward leadership. Learning experiences are most productive when they occur over time, provide feedback, and ground the leaders in science content, teaching and learning, and authentic work experiences (Fullan 2001; Kaser et al. 2002; Wei, Darling-Hammond, and Adamson 2010). Districts need to develop leadership programs that embrace these attributes, and/or encourage their teacher leaders to participate in these types of leadership experiences through programs such as the California Science Project, the K-12 Alliance/WestEd, and the California Science Teachers Association.

There are also multiple, effective teacher leadership strategies. A few strategies are addressed here (adapted from Garmston and Wellman 1999):

- *Presenting:* The science leaders seek to extend and enrich knowledge, skills or attitudes of the audience around the CA NGSS. Presentations can be made at staff meetings, district meetings, or professional organizations (e.g., CSTA, NABT, APPT).
- *Consulting:* The science leaders serve as informational specialists or advocates for content. They deliver technical knowledge and often encourage the participants to use a certain strategy or adopt a particular program that aligns with the CA NGSS.
- *Facilitating:* The science leaders conduct meetings in which the purpose might be dialogue, shared decision making, planning or problem solving around the CA NGSS. Facilitating Professional Learning Communities in which the grade level or staff utilizes data to make decisions about instruction, is one example.
- *Coaching:* The science leaders helps others take action toward their goals through planning, reflection, and self-direction. Coaching may be mentoring or instructional, peer or supervisory. Wei, Darling-Hammond and Adamson (2010) document the efficacy of coaching that includes modeling instruction, observation, and feedback.

Teacher leaders should be given opportunities to lead. The challenge for most schools and districts is finding resources (time, personnel, and funding) to support it. Districts and schools are encouraged to consider how to

- use teacher leaders through the various stages of CA NGSS implementation—awareness, transition, full implementation;
- include elementary science specialists who build a culture of science with students and teachers, collaborate with teachers in planning, co-teach with teachers, and provide content and material support;
- build on collaborative structures that already exist for the CA CCSS and can be transitioned to CA NGSS with techniques such as using Professional Learning Communities, staff meetings that include teachers teaching other teachers, and grade-level meetings that adopt a stance of inquiry and shared leadership;
- use or initiate strategies such as instructional rounds or critical friends groups aligned to the CA NGSS;

- provide time and space for leaders to lead and reflect on their leadership;
- create teacher leadership positions such as a teacher on special assignment (TOSA) or a science teacher leader on the district professional learning team;
- use technology for teacher leadership. For example, while it may be ideal for teachers to observe exemplary teaching in a face-to-face environment, videos of teaching can be used to simulate the experience followed by collaborative conversations about instructional practice. Teachers and instructional coaches can also engage in online communities of practice to share ideas, ask questions, provide feedback on student work or lesson plans, and a variety of other tasks that are suitable for collaboration in virtual environments.

Administrative Leadership and Professional Learning

Realizing the vision of the CA NGSS requires complex changes to the education system and to its culture. For these changes to be enacted and sustained, leadership must be employed at multiple levels and across time so that the CA NGSS will be integrated into curriculum, instruction, and professional learning and into the culture of schools and school districts. Site and district administrators play a key role in creating safe learning environments for students and teachers and in establishing policies and procedures that facilitate the full implementation of the CA NGSS, including empowering teachers and site administrators to use resources flexibly. This section discusses how administrators can address their professional leaning aligned to the CA NGSS vision to enable them to create the structures and support for teachers to implement the CA NGSS in the school and classroom.

Site principals are particularly important. Based on commonalities of successfully implemented programs, Fixsen and colleagues (Fixsen et al. 2005, Fixsen and Blase 2009) identified key core implementation components to guide principals in supporting behavioral and system changes to implement and sustain innovation. Achievement levels are higher in schools where principals (a) undertake and lead a school reform process; (b) act as managers of school improvement, including strategically allocating resources and support; (c) cultivate the school’s vision; (d) make use of student data to support instructional practices; (e) help individual teachers through support, modeling, and supervision; (f) provide assistance to struggling students; and (g) foster collaboration and engage families and community (Leithwood and Jantzi 2005; Williams, Kirst, and Haertel 2005; Waters, Marzano, and McNulty 2003).

To enable administrators to become competent with the CA NGSS, district and school administrators should take the following steps:

Promote a culture of collaboration

- Join teachers as learners and engage in collaborative work with colleagues to transform new classroom experiences into teaching expertise (Weinbaum and Supovitz 2010; Weinbaum et al. 2004).
- Work with teachers to plan and develop tools to provide relevant feedback regarding observable instructional practices representing all three dimensions of CA NGSS learning.
- Form networks of their colleagues to try new strategies (e.g., science-oriented instructional rounds, CA NGSS-aligned observation protocols) with time for reflection and feedback as part of the continuous improvement cycle.
- Attend science professional conferences (e.g., NSTA, CSTA, State CA NGSS Roll Outs, local programs offered by the local county office of education) with other leaders to exchange and reflect on their own experiences.

Educate themselves

- Learn about what high-quality science instruction looks like in the classroom; the three dimensions of the CA NGSS and how they are connected; and the exploratory and experimental approaches of instruction that support student and teacher learning.
- Read *The Next Generation Science Standards Systems Implementation Plan for California* (CDE 2014a) (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link3) and enact the suggestions for the LEAs for the eight strategies, with particular attention to the professional learning strategy.
- Read and understand the *California Common Core State Standards for Literacy in History/Social Studies, Science and Technical Subjects* and the role of science teachers in providing access to those standards for all students.
- Read and understand the *CA ELA/ELD Framework* and the vision for shared responsibility for literacy and integrated ELD.
- Read and understand the *CA Model School Library Standards* and the role the integration of these standards play in preparing students for college and career readiness.
- Understand the meaning of *integrated science* driven by phenomena and how this differs from coordinated science (particularly important for the middle grades using the Preferred Integrated model, but relevant to all levels).

Prioritize science alongside other instructional needs

- Convey high expectations for science instruction aligned with the CA NGSS.
- Work with all stakeholders to ensure that the Local Control Accountability Plan (LCAP) addresses the implementation of the CA NGSS and specifically addresses professional learning for teachers, administrators, and address the needs of any of those pupils to whom one or more of the definitions include low income, English learner, and foster youth.
- Modify policies and procedures to meet the goal of providing access to all science standards for all students.
- Develop a communication plan for teachers, parents, and community that ensures consistent messaging and emphasizes the need to support teachers transitioning to CA NGSS.

According to City et al. (2009), "In most instances, principals, lead teachers, and system-level administrators are trying to improve the performance of their schools without knowing what the actual practice would have to look like to get the results they want at the classroom level." To support the CA NGSS, district and school administrators need to understand what high-quality science instruction looks like in the classroom. By seeing themselves as chief educators, they will support their teachers more effectively.

Administrators often use instructional rounds or other observation protocols designed to provide structure to classroom visitations and observations. New protocols will be needed for administrators to conduct classroom observations of instruction and learning aligned with the CA NGSS. Protocols should also contain the instructional strategies for the CA NGSS classroom described fully in the "Instructional Strategies" chapter. Having a tool to focus observations on the three dimensions of the CA NGSS will provide much needed feedback to the teacher about how well the lesson provides opportunities for students to experience all three dimensions. Tools such as the Science Classroom Observation Protocol developed by RMC Research Corporation in collaboration with the Washington's State Leadership and Assistance for Science Education Reform (RMC Research Corporation 2010) provide a suggested framework for classroom observation to support CA NGSS implementation. The observations reveal what students are doing, such as (Banilower et al. 2008)

- revealing preconceptions, initial reasoning, or beliefs;
- using evidence to generate explanations;
- communicating and critiquing their scientific ideas and the ideas of others;
- making sense of the learning experience and drawing appropriate understandings;

- making connections between new and existing scientific concepts by understanding and organizing facts and information in new ways;
- reflecting on how personal understanding has changed over time and recognizing cognitive processes that lead to changes.

All the components discussed above must be integrated into the culture of the organization implementing the changes. Educational leaders are essential in maintaining the vision of equitable science opportunities for all students by promoting strategies and identifying resources for equitable access and equitable participation in science learning.

Another observation tool is the Ambitious Science Teaching observation rubric. Ambitious Science Teaching supports students of all backgrounds to deeply understand science ideas, participate in the activities of the discipline, and solve authentic problems. Information and tools for the implementation of Ambitious Science Teaching are available online at https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link4.

Shared Leadership and Responsibility

The *ELA/ELD Framework* (CDE 2015) discusses the critical need for shared leadership and responsibility. Skilled and inspirational leadership is also essential to the successful implementation of the CA NGSS. Leadership, as conceptualized in this framework, is distributed among many individuals within a school and district. It is not confined to administrators but involves a range of individuals who lead important professional systems and practices. Key leaders motivate, guide, support, and provide the necessary resources, including time and appropriate compensation, to teachers and others to accomplish the many goals and tasks associated with implementing a high-quality program. All leaders at the district and school levels are actively engaged in leading the implementation of this framework and related standards.

Research on effective professional learning (Desimone 2009) and on effective implementation, or change, (Fixsen and Blase 2009) points to collective participation and facilitative administrative action as important elements of success. *Collective participation* occurs when teachers in the same school, grade level, or department participate in the same professional learning. This collective participation has the potential to promote collaboration, discussion, and shared responsibility (Borko 2004; Darling-Hammond and Sykes 1999; Grossman, Wineburg, and Woolworth 2001; Lewis, Perry, and Murata 2006; Stoll and Louis 2007; Wilson and Berne 1999). Collective participation resonates with Wenger's (1998) social theory of learning, which suggests that learning, rather than being solely an individual process, is social and collective and that many people learn in communities of practice. Most researchers and reformers agree that in communities of practice teachers work together to

- reflect on their practice, forming social and professional bonds;
- develop shared understandings about practice and work to refine particular effective practices;
- collaborate on problems of practice using evidence, such as student work and assessment data;
- view their teaching from a critical stance, confront challenging topics (such as approaches they have tried but that have failed), and engage in difficult conversations (such as beliefs and attitudes about groups of students);
- provide mutual support and mutual accountability;
- learn to deal constructively with conflict;
- focus on their improvement to achieve student improvement.

Working together to create new program supports, examine student learning, and solve problems is the concrete path to shared responsibility and ownership for student learning outcomes. As goals and priorities are articulated by leaders and all school staff share in deciding next best steps, all teachers, specialists, administrators, and other staff need to assume leadership roles for implementing elements of the plan. These roles are carried out in collaborative settings designed to maximize trust and mutual support. The contributions and worth of every member of the team are honored, nurtured, and supported within a truly collaborative culture. Although conflicts will arise, leaders use effective strategies for leading collaborative work and establishing agreements for “how group members work together, think together, [and] work with conflicts” (Garmston and Zimmerman 2013) to arrive at resolution and creative solutions (CDE 2015).

Critical Issues

According to Loucks-Horsley et al. (2010), issues “critical to the success of programs everywhere, regardless of context” include (a) capacity building for sustainability, (b) making time for professional development, (c) developing leadership, (d) ensuring equity and diversity, (e) building professional culture, garnering public support, and (g) scaling up. The idea is that prior consideration of these factors can help professional developers avoid commonly encountered pitfalls and can help to ensure success of the program. Consider leadership as “taking responsibility for something you care about” (DiRanna and Osmundson 2008). Consider equity not only in terms of participants but also in terms of logistics (e.g., summers, weekends, childcare). Consider how every teacher and administrator in the district will be knowledgeable about the CA NGSS and capable of teaching in or supporting a program that aligns with the vision for the CA NGSS. Consider alliances with other educational efforts—how can what you learned from CA CCSS inform your professional learning for the CA NGSS?

Systemic Support for Professional Learning

To reform classroom instruction that aligns with the vision of the CA NGSS, teachers must feel supported in adapting and revising their day-to-day instructional practices and have the time to reflect on how they impact students' learning. It is the responsibility of educational leaders to create within the school or district structures appropriate and sufficient space and time to allow the development of teacher-led collaborations (Weinbaum and Supovitz 2010). Leaders will also need tools to gather evidence regarding the implementation process in order to evaluate (both formally and informally) their school's progress. This evidence will allow them to design timely support mechanisms to foster implementation of reforms while also assessing students' opportunities for equitable learning (NRC 2013). This alignment of competencies and roles between teachers and school and district leaders is best realized within a system of distributed leadership (Harris and Spillane 2008) in which motivation and trust constitute the fertile ground to accomplish goals and tasks associated with implementing the CA NGSS while also coordinating with the implementation of other standards-based efforts. Two key components for implementation—tools for implementation and funding—are discussed below.

Tools for Implementation

Much is currently being tested and learned from the nationwide implementation of the CCSS, and action-planning tools are being developed to assist school leadership teams in the process of implementing the interconnected components of the CCSS. These tools are also useful resources to guide the parallel implementation of the CA NGSS in California classrooms while targeted CA NGSS materials are being developed:

- Leadership Planning Guide for California: Common Core State Standards and Assessments Implementation: https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link5
- Implementation of the Common Core State Standards: A Transition Guide for School-Level Leaders: https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link6.
- Association of California School Administrators: https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link7
- CA NGSS K-8 Early Implementation Initiative: https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link8

The Next Generation Science Standards Systems Implementation Plan for California (CDE 2014a) outlines the following multiple-phase approach in preparing for and implementing the CA NGSS:

- The *awareness phase* represents an introduction to the CA NGSS, the initial planning of systems implementation, and establishment of collaborations.
- The *transition phase* is the concentration on building foundational resources, implementing needs assessments, establishing new professional learning opportunities, and expanding collaborations between all stakeholders.
- The *implementation phase* expands the learning support; fully aligns and integrates curriculum, instruction, and assessments; and effectively integrates these elements across the field.

Classroom Space and Equipment

Faithful implementation the CA NGSS will require consideration of classroom space and equipment necessary for students to fully engage in the performance expectations and supporting SEPs, DCIs, and CCCs. Many physical and biological concepts are introduced in elementary grades—with appropriate modifications for age and brain development—that require the safe use, storage, and disposal of materials that in the previous way of teaching science were introduced in the middle grades and high school.

It is important to recognize that teaching science as envisioned by the CA NGSS requires that students do science. This means that schools and classrooms must contain equipment and consumable materials to allow all students to engage in the science and engineering practices. Although some equipment may be shared across classrooms or grades, all classrooms will need to have materials on hand for ready access to investigations at conceptually appropriate times.

Remember that CA NGSS science instruction begins with engaging students in phenomena, observable features of our natural world. Throughout the course of instruction, students will complete numerous hands-on investigations and engineering challenges, including teacher- and student-designed experiments as they explore science concepts related to a specific phenomenon. There must be enough equipment and materials for students to work in groups of two to four.

While it is impossible to predict everything that will be used in classrooms of each grade, it is possible to predict some minimal needs for each grade band. The list of materials recommended by the California Science Teachers Association (CSTA) contains the minimum materials needed for classrooms. The full list is hosted on the CSTA Web page at https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link9. It is worth noting that this list represents only the permanent equipment list and makes no commentary about consumable materials (for example, plastic straws, cups, grocery store chemicals, balloons, plastic bags) or teacher-preferred materials (like density boxes) that are a critical component to the science classroom.

It is recommended that districts form committees of science teachers representing all grade levels, as well as specialists, to determine the actual needs of the classrooms in their district. Science teachers are in the best position to know what materials already exist within the district and what their needs are as they fully implement the CA NGSS. District budgets also need to accommodate the increased costs of consumable materials that will be required. Each grade level and each science course will need to purchase and replenish consumable materials as students are engaged in the practices of science and engineering.

All administrators, teachers, and paraprofessionals who support science instruction should be familiar with the concepts and practices of laboratory safety. As noted in the *Science Safety Handbook for California Public Schools* (CDE 2014b), all chemicals are commonly described in terms of their physical, chemical, or biological properties. Several classification systems exist, including the United Nations Globally Harmonized System of Classification and Labelling of Chemicals and the U.S. Department of Transportation (DOT) Hazardous Materials Transportation guidelines. It is important to know both classification systems when hazardous materials are transported and stored. Chemicals are classified by characteristics such as flammability, corrosivity, and radioactivity. These hazardous chemical classifications are listed on the Material Safety Data Sheets for each chemical in the laboratory.

Chemicals may also be classified based on the type of hazard they pose (acute or chronic), such as a reproductive toxicant, carcinogen, or chemical sensitizer. This classification system is based on the inherent toxicity of a substance, which is a function of the chemical's molecular structure, physical state, dose, and route of exposure. Toxicity may vary, depending on factors such as the gender, age, and health status of the victim.

In general, chemicals used in experiments are classified by their functional groups. Classification information is important for determining chemical compatibility and reactivity, procedures for conducting experiments, safe bulk storage of chemicals, and waste collection and labeling. Knowledge of properties may also be used to predict the likely behavior of chemicals and recognize and avoid potentially dangerous situations. The *Science Safety Handbook* and more information on laboratory safety is available on the CDE Science Web page at https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link10. Appropriate classroom space is also important for students to have access to the necessary computing and printing equipment required to ensure three-dimensional learning for the computational thinking, computer modeling, and data analysis that was also previously introduced in later grades. Access to a computer lab will work in some instances, however, there are opportunities for increasing engagement with immediate feedback if equipment is readily available.

Programs and Partnerships to Support CA NGSS Learning

While many would consider professional learning for teachers and administrators to be the lynchpin for the implementation of the CA NGSS, it cannot be effective without support from the entire educational system. A comprehensive and effective professional learning system involves everyone who impacts the classroom: pre-service institutions, school board members, superintendents, district office personnel, school administrators, school staff (including expanded-day staff), parents, guardians, and families.

These key players help shape policies that support CA NGSS science education. They provide a quality teacher pipeline; promote collaboration among an experienced science leadership network; allocate adequate funds to attract/maintain a well-qualified science teaching staff; and provide teachers with exemplary science curriculum materials, space, resources (grade-level appropriate equipment and materials) for three-dimensional learning, and time for high-quality professional learning. Teachers and administrators create safe environments for student exploration and learning and must be willing to collaboratively learn, analyze, and reflect in a cycle of continuous improvement. Informed parents, guardians, and community members can be active players in supporting policies and practices that uphold quality professional learning experiences. By working as a team, the stakeholders can ensure that all students have the opportunity to achieve scientific literacy.

Innovate: A Blueprint for Science, Technology, Engineering, and Mathematics in California Public Education (STEM Task Force 2014) recommends that schools and districts "integrate the CA CCSS into programs and activities beyond the K-12 school setting." It also suggests providing "professional development to district administrators, school principals, and afterschool program directors on how to collaborate to incorporate into afterschool/extended-day programs those activities that enrich and extend the CA CCSS-related learning initiated during the regular day." Planning for opportunities to extend students' learning beyond the classroom is an important aspect of the implementation of the CA NGSS. In fact, those programs conducted before and after school, during summer and intersession, and at informal sites, such as museums and science centers, not only focus on developing academic abilities but also build interest in science and engineering and help students to develop social and emotional skills needed for effective engagement in science and engineering practices. For this reason, it is important to cultivate a broad range of systems fostering community support to enhance in-school as well as out-of-school learning opportunities. This will allow students to engage in three-dimensional learning across multiple spaces and through extended time.

This section provides recommendations on how to engage significant stakeholders beyond school personnel and how to develop partnerships.

Role of Parents, Guardians, and Families

While the school classroom is the primary learning environment for science education, home and community also play significant roles. Through involvement at every level, parents, guardians, and families can motivate students to develop a lifelong appreciation of science learning. Families can also provide a supportive home setting for students to learn and prepare for school. Enlisting parents, guardians, and families in understanding and supporting the CA NGSS and the new classroom environment is key. Because these standards involve new approaches in the science classroom and will likely involve new types of tasks for student homework, it is critical to educate parents and guardians about what to expect and about the reasons and research behind the changes. Educating and engaging parents and guardians should include opportunities for them to experience a three-dimensional learning opportunity (including support for parents who speak languages other than English), not simply written descriptions of it. Furthermore, parents and guardians who become more knowledgeable through such an experience can more effectively support students' learning beyond the classroom. Parents and guardians can monitor their children's learning progress not just for content knowledge, but for understanding of and engagement in science and engineering practices or evoking application of crosscutting concepts as a problem-solving strategy. Parents and guardians can also foster social interactions (e.g., by providing support for collaborative classroom or out-of-classroom projects) and become involved in educational activities promoted at the school site (e.g., Science Nights, Science Clubs, and Science Olympiads).

A model to support the development of family and school partnerships is the National Parent Teacher Association, which has developed standards for Family-School Partnerships (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link11). These standards focus on several aspects of the partnership providing recommendations on how to foster effective communication and trust to support students' success. In addition to the standards, they have developed a guide that provides a rubric with examples for what family-school partnerships look like at the emerging, progressing, and excelling levels. Parents, guardians, families, and school leaders may want to use these examples to evaluate and enhance the family-school collaboration at their school site. Specifically, involving parents who have a background in science and engineering will help develop partnerships with the community that can provide much-needed support for classroom instruction.

The *ELA/ELD Framework* provides specific suggestions for parent, guardian, and family involvement when those families speak a language other than English or are new to the United States. When possible, having parents who have experience with science and engineering and speak a home language that students also speak would be a great support for the parents of those students who are not as experienced with science and engineering (CDE 2015, chapter 11).

Community and Stakeholder Partnerships

Professional organizations, including those who support educators in both formal and informal learning settings, the business community, and many other groups can play an important role in the implementation of the CA NGSS by providing resources, feedback, and support to schools and the broader education system. The support provided can be funding for school-site or district-level initiatives or expertise in the form of professional networks and collaborations that enable ongoing partnerships to support classroom teachers well beyond the initial CA NGSS implementation. This section presents information about the various types of partnerships and provides suggestions regarding their formation and successful involvement. Characteristics of effective partnerships that support the CA NGSS are (CDE 2015)

- cross-sector in nature, often linking partners from government, business, diverse learning institutions (K–12, expanded and informal learning, and higher education), and other community-based organizations and nonprofits;
- highly collaborative and participatory, and ensure that educators, parents, and guardians are part of the decision-making process;
- focused on providing high-quality learning opportunities that align with the CA NGSS as well as future workforce needs;
- hubs for communication, learning, and sharing;
- responsive to local and regional community needs and leverage local assets and resources.

Types of Partners

A broad range of potential partners exists to support implementation of the new CA NGSS. National partners such as Achieve, the organization that helped to organize the development of the NGSS; the National Science Teachers Association; and the Council of State Science

Supervisors have all been intimately involved in the development of NGSS—supporting broad aspects of their implementation and providing specific resources and professional development opportunities to support teachers in the classroom. For example, Achieve recently launched a national network to support NGSS implementation, and it also developed the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric to help educators evaluate the level to which a curricular resource may align with the CA NGSS as well as other resources. For more information, visit https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link12.

Groups at the state level, including the California Science Teachers Association, the California Science Project, K-12 Alliance/WestEd, the California County Superintendents Educational Services Association and its Curriculum Instruction and Steering Committee, the Association of California School Administrators, Children Now, and other state-wide networks provide a wide range of resources and opportunities for educators and other partners interested in supporting science education. Many of these groups have regional or local affiliates that provide resources targeted to local priorities and needs.

Institutions of higher education (IHEs) also offer a range of resources to support implementation of CA NGSS. As one example, the California State University system has created an NGSS Teaching Commons that provides a number of resources to support classroom teachers in implementation of the CA NGSS (visit https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link13). College and university faculty can also support the implementation of CA NGSS by joining in more formal partnerships with their local schools and providing them with speakers in science and engineering. One example is the University of California San Francisco (UCSF) Science and Health Education Partnership (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link14). Since 1987, UCSF has promoted partnerships between scientists and educators in San Francisco Unified School District with the goal of mutual support for teaching and learning.

Business and industry partners also provide a wide array of resources for educators in support of NGSS. For example, The California STEM Learning Network (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link15), a series of regional networks focusing on advancing STEM education, has fully supported NGSS at the state and national level by building partnerships that connect educators with business and community assets in an effort to strengthen and expand access to STEM learning in both formal and informal settings and increase interest in STEM-related fields for all students in California. These networks are also a resource for scientists, engineers, and technical employers who can speak to the need for the type of knowledge and twenty-first century skills that are the target of CA NGSS.

Finally, a number of *nonprofit organizations* also provide resources for educators implementing the CA NGSS in their classrooms. For example, the Teaching Channel (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link16), Howard Hughes Medical Institute (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link17), and PBS Learning Media/KQED (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link18) have a significant number of free, catalogued resources that align with CA NGSS.

These organizations can also provide valuable support for teachers during after-school programs as they practice and refine their capacity to integrate three-dimensional learning into their instruction. One example is Project GUTS, a middle grades program that integrates computer modeling and simulation of community issues as complex systems phenomena, which has been used in after-school spaces as a "sandbox" for teachers to experiment with new pedagogy, content, and practices. In this project, master teachers and STEM professionals, serving as facilitators during after-school club meetings and professional development workshops, mentored middle grades science teachers. After-school clubs also provided the venue for teachers to observe and understand student learning and engagement.

The Value of Effective Partnerships

The CA NGSS emphasize real-world interconnections in science and are best achieved by hands-on and inquiry-based teaching practices. Partnerships among schools, businesses, higher education institutions, science-rich institutions, and community organizations can provide authentic and engaging learning opportunities and resources. These partnerships can also play a critical role in creating meaningful connections between curriculum taught in the classroom and students' personal interests, career aspirations, and higher-learning goals.

While the partnerships described above are crucial to expanding science learning for educators and students, some challenges need to be addressed. For example, how do partners effectively communicate? How can partners create an infrastructure that supports their ongoing work? Educators may be hesitant to approach potential business and industry partners due to perceived differences in culture and time limitations. For business partners, approaching potential education partners can be equally challenging.

Given these challenges, what criteria would ensure productive partnerships to support students' learning in science? The following recommendations are provided to start conversations around effective partnerships:

1. *Articulate a shared agreement on vision, goals, and processes.*
   Leaders of productive science partnerships must work together to create opportunities and adapt to build a shared vision and goals, as well as to develop processes to

support student learning. The collaborative leadership must work together to develop mutual understanding, respect, and trust so that the partnership can benefit the children and the supporting teacher(s). Mutually beneficial partnerships revise and revisit these goals over time.

2. *Focus on student learning and engagement in science.* (NRC 2010b; Bevan et al. 2010).

   As educators, we need to encourage children to have direct or media-facilitated interactions with phenomena of the natural and designed worlds in ways largely driven by the learner. The experiences from these partnerships should provide multifaceted and dynamic portrayals of science that build on a child's prior knowledge and interests and pique their wonder and excitement about science. In these settings, children should be allowed considerable choice and control over how they engage and learn. Children learn through a rich variety of experiences over time and across settings. Effective partnerships work synergistically in expanding student learning in both in-school and out-of-school settings. In addition to increasing student learning and engagement, science partnerships can engage students in multiple ways—cognitively, socially, emotionally, and physically; strengthen students' attitudes and identity toward science and science learning; advance teachers' conceptual understanding in science; and support teachers' integration of three-dimensional learning in science.

3. *Pay attention to relationships.*

   Initiating and sustaining productive relationships across institutions take time and effort from both sides. As schools and districts consider partnerships with STEM institutions, it is important for partners to "deeply respect and honor each other's unique expertise" (National Academy of Engineering and National Research Council 2014). Working together toward common goals requires open communication, mutual respect, and a shared understanding.

Examples of Partnerships in California

In California, a broad array of partnerships can be utilized to support CA NGSS:

- *Professional development partnerships* provide opportunities for science educators to augment their professional learning. Some examples include the Industry Initiatives for Science and Math Education (IISME) and the California Science Project, a collaboration among K–12 and higher education science educators, and the K–12 Alliance/WestEd.
- *Career readiness/exploration partnerships* integrate academic and career technical

education through job shadowing, mentoring, and internships. Some examples include MESA (Mathematics, Engineering, Science Achievement), Linked Learning, and California Partnership Academies.

- *Regional and local partnerships* may be coordinated by the county offices of education, chambers of commerce, workforce investment/development boards, or higher education institutions. Some examples include the Gateways East Bay STEM Network hosted by CSU East Bay, and Unite LA hosted by the Los Angeles Chamber of Commerce and part of the California STEM Learning Network, local water districts, and other governmental agencies. *Informal learning opportunities* offered by science centers, museums, after-school programs, libraries, parks, and community-based organizations. These institutions provide students with experiences that can support and augment what happens in the classroom and also provide parents, guardians, families, and the larger community opportunities to participate in science-rich experiences. Two examples include the Power of Discovery: STEM (https://www.cde.ca.gov/ci/sc/cf/ch12.asp#link19), a program that supports high-quality STEM learning programs at hundreds of after-school sites across the state, and Making the Grade, a new effort launched by the Discovery Science Center focused on NGSS-aligned exhibits and professional learning opportunities for students and educators.

Many of these partnerships provide financial and in-kind support for instructional materials for classroom activities, host activities such as science or career fairs, and match professionals with teachers or students.

As described in this section, a range of public and private organizations, agencies, and businesses can support the implementation of science education aligned with CA NGSS by seeking to create formal and informal partnerships with schools and districts. Schools and districts are encouraged to use community resources to (1) provide the additional adult support and instructional materials that students need to meet their education requirements in and out of the classroom, and (2) start to develop students' ideas and associated education pathways about types of workforce, careers, and higher education options as they relate to their local communities and beyond. In this way, more opportunities can be realized to connect the education that students are acquiring in the classroom to the world where students live.

Conclusion: An Ecosystem Approach

To end, collaboration among schools and various science sectors can be compared to an ecosystem—with its diverse organizations and interrelationships. “Ecosystems are not efficient, they evolve over very long time periods, and they constantly change” (National Academy of Engineering and National Research Council 2014, 50). There will not be any one program or organization that fits all of the learners’ needs or answers all of their questions. It is the collection of student experiences that help students develop stronger practices, dispositions, and understandings of how the natural and designed-world operates.

Below is a set of questions that can be used by teams to get started in thinking about how to build this ecosystem for the community of children and adult learners in STEM (Traphagen and Traill 2014; National Academy of Engineering and National Research Council 2014, 18).

1. How does this partnership build the capacities of the educators who are working with students?
2. What tools and structures are needed to make this collaboration successful and sustainable?
3. What processes do we need to link in- and out-of-school STEM learning so that it is a coherent experience for our students?
4. How do we deepen students’ STEM interests over time?
5. How can classroom learning and instruction support the out-of-school time experiences? And vice versa?
6. How can we engage families and communities and help them understand and support children’s STEM success?

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