K–12 Science Education in the United States
A Landscape Study for Improving the Field

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As we look to elevate the status of science education in the U.S. and to broaden the involvement of underrepresented groups in ongoing reform efforts, we need a field-level agenda for change. To that end, this report includes recommendations to inform improvements over the next 10 years in service of making science education a priority for all.

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PREFACE

The Education program at Carnegie Corporation of New York builds on a legacy of investments in education involving standards reform, improving teaching practices, supporting school and system leaders, and increasing the supply of and demand for high-quality instructional materials and aligned assessments. These efforts have included sustaining the vision and implementation of college- and career-ready standards in science education. Since 2009, the Corporation has awarded 92 grants to 32 organizations related to investments in the field of public K–12 science education, representing more than $51 million. Most of the grants have focused on instructional materials, professional learning, and assessments.

Science education in the United States was revolutionized following the 1957 launch by the Soviets of *Sputnik*, the world's first satellite. The subsequent Sputnik era, as it came to be known, spurred an increased focus on science education, leading to a new generation of scientists and engineers. Today, with challenges like the ongoing threats of global climate change and the COVID-19 pandemic, we are facing a new "Sputnik moment." We must respond to the current crisis in science education with an equally intense focus. *How* we respond will impact the nation's future on issues ranging from public health and the environment, to racial equity and economic prosperity.

To better understand the state of K–12 science education today, we commissioned Horizon Research to develop a landscape study. The report assesses the progress over the last decade toward the vision of science instruction provided in 2012 by the Corporation-supported Framework for K–12 Science Education, published by the National Research Council, and the subsequent development of the Next Generation Science Standards, a set of research-based, K–12 science content standards.

As we look to elevate the status of science education in the U.S. and to broaden the involvement of underrepresented groups in ongoing reform efforts, we need a field-level agenda for change. To that end, this report includes recommendations to inform improvements over the next 10 years in service of making science education a priority for all.

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EXECUTIVE SUMMARY

In 2022, Carnegie Corporation of New York commissioned Horizon Research, Inc. (HRI) to assess the progress of the field of K–12 science education in the United States since 2012, when the National Academies of Sciences, Engineering, and Medicine (NASEM) published *A Framework for K–12 Science Education* (referred to as "the *Framework*"; National Research Council 2012).

For the last decade, the *Framework* has shaped reform efforts across all components of K–12 science education — including state standards, instructional materials, professional learning, assessments and accountability policies, instruction, and preservice teacher preparation. Ten years after its publication, it is still one of the most frequently downloaded reports from the National Academies Press (NASEM n.d.). Most notably, the *Framework* drove the development of the Next Generation Science Standards (NGSS; NGSS Lead States 2013), a set of research-based, K–12 science content standards developed by states to improve science education by setting expectations for what all students need to know and be able to do.

K–12 science education is complex and best thought of as a system of interrelated components. These include state standards, instructional materials, professional learning, classroom instruction, assessments and accountability policies, and preservice teacher preparation. To characterize each of these components, HRI interviewed 50 stakeholders and surveyed several hundred, including K–12 teachers, district and state science supervisors, and college and university faculty. HRI also reviewed reports that synthesized the field's knowledge base in each area.

To study progress in the field of K–12 science education during the last decade, HRI adopted the Bridgespan Group's Field Building for Population-Level Change model (Farnham et al. 2020), which identifies five characteristics necessary for building a field: a knowledge base, actors, a field-level agenda, infrastructure, and resources.

Bridgespan's model acknowledges that field building often takes decades and progresses through phases that align with these five characteristics. In the *emerging* phase, a field is lacking in all five characteristics. In the *forming* phase, the knowledge base is growing, and actors increasingly draw on it. Led by widely respected individuals, actors begin to rally behind a field-level agenda that takes priority over individual initiatives. Infrastructure becomes more formalized, and funders begin to pool their resources, creating coherent funding streams. Finally, in the *evolving and sustaining* phase, a robust knowledge base is available to a diverse, stable, complementary set of actors. The field-level agenda has broad buy-in from stakeholders and becomes formalized in policy and regulations. Infrastructure is sustainable, and a consistent set of funders supports the work, providing dependable financing.

Using Bridgespan's model and based on its own landscape survey, HRI assessed most of the components of the field of K–12 science education as either emerging or forming. Only state standards are sufficiently advanced to have reached the evolving and sustaining phase. This report takes a close look at the progress that has been made (Table ES-1) and makes the following recommendations for improvements.

TABLE ES-1

Status of K–12 Science Education

PHASE

EMERGING	FORMING	EVOLVING AND SUSTAINING
COMPONENT		
Professional learning	Instructional materials	State standards
Instruction	Assessments and accountability	
Preservice teacher preparation		

RECOMMENDATIONS TO IMPROVE THE FIELD

State Standards

- The long-term viability of the NGSS and similar standards will depend on broad public support, particularly from current students and their parents and guardians, who often lead demands for change. To that end, there is a need for efforts at the state and national levels to disseminate accurate depictions of standards-aligned instruction and explain the benefits for students and society. An important societal benefit is the potential to close achievement and opportunity gaps in science by race/ethnicity.

Instructional Materials

- States, school districts, and schools should ensure teachers are equipped with high-quality instructional materials and supports to meet the needs of their students rather than asking teachers to create their own or find instructional resources on the internet. Developing coherent, yearlong, standards-aligned curricula is possible, but it requires time and expertise. Asking individual teachers to create these materials is unreasonable. Rather, teachers should be provided high-quality instructional materials and supported to adapt them to students' needs and their local context.
- States and districts should increasingly allow for the adoption of open educational resources (OER), which some states already do, in addition to instructional materials created by commercial publishers. They should also increase flexibility in how budgets for instructional materials can be spent, allowing districts and schools to purchase commercial products (e.g., print materials and consumable and nonconsumable supplies) associated with standards-aligned OER materials.

Professional Learning

- One way to improve professional learning opportunities is to center them on helping teachers use high-quality, standards-aligned instructional materials as they become available. Rather than focusing on teachers' content knowledge or teaching strategies alone, curriculum-based professional learning does both in the context of the instructional materials teachers are using. States and districts should provide curriculum-based professional learning focused on high-quality instructional materials, including OER materials.
- It is imperative that science teachers have more ongoing opportunities for professional learning. Expectations for field-level change should remain low as long as the typical teacher has less than five days of professional learning focused on science teaching over three years.
- School and district administrators who support and evaluate teachers of science should be provided with opportunities to learn about the standards and what standards-aligned instruction looks like.

Instruction

- States can make the transition to standards-aligned instruction easier for teachers by using existing infrastructure. For example, instructional coaches are relatively common in ELA and mathematics. States could direct more coaching support to science. Similarly, many states have regional centers that support schools and districts with professional learning and other services, but they tend to prioritize ELA and mathematics instruction. These centers could give more priority to science.
- As the work of improving science instruction progresses, states should put systems in place to identify and track inequities in access to standards-aligned science instruction to ensure that existing gaps begin to narrow and that new gaps do not appear. These systems should prioritize identifying and supporting schools and districts that need help, not penalizing them.

Assessments and Accountability

- Education accountability is ingrained in state and federal policy, and it prioritizes ELA and mathematics. Until science is elevated to the same level in these policies, it will continue to receive fewer resources, both financial and nonfinancial. States should include science in their accountability systems as a first step toward giving science the priority it deserves.
- Coupled with policy changes, the nation needs systems of standards-aligned science assessments that benefit students by informing changes in instruction. These should include assessments that align with the standards-aligned materials districts have adopted, enabling districts to monitor student performance locally and more frequently rather than relying on end-of-year state assessments. Assessments like these would provide better information about student learning and relieve some of the pressure teachers and students feel due to state-administered assessments.

Preservice Teacher Preparation

- Those leading the reform of preservice teacher preparation should develop a strategy that involves a large number of preservice faculty in developing model programs for preparing science teachers for standards-aligned instruction using high-quality instructional materials.
- With the growing availability of high-quality, standards-aligned instructional materials, teacher preparation programs should include a requirement for preservice teachers to demonstrate the ability to identify and use these types of materials.
- Preservice faculty should have opportunities to develop their understanding of the *Framework* and the NGSS. One strategy to accomplish this is for preservice programs to partner with schools and districts engaged in professional learning focused on standards-aligned instructional materials.

INTRODUCTION

The COVID-19 pandemic galvanized the scientific community as few other events have. Several research efforts produced effective vaccines with unprecedented speed, drawing comparisons to the space race that followed the Soviet Union's launch of Sputnik in 1957. Sixty-five years later, the pandemic has powerfully demonstrated how the health of a nation depends on science. The pandemic has affected every American on a daily basis. It has also highlighted the high cost of low science literacy. Resistance to masking and vaccines, based largely on misinformation (and disinformation), almost certainly cost hundreds of thousands of lives. And just as Sputnik did, the pandemic has motivated the nation to take stock of K–12 science education.

In addition to marking the 65th anniversary of Sputnik, this report marks the 10th anniversary of a watershed moment in K–12 science education. An effort to develop new college- and career-readiness standards for science began in 2007 with the Commission on Mathematics and Science Education, established by Carnegie Corporation of New York and the Institute for Advanced Study. The commission's report, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy* (Carnegie Corporation of New York 2009), put in motion a series of studies by the National Academies of Sciences, Engineering, and Medicine (NASEM), and in 2012, NASEM published *A Framework for K–12 Science Education* (henceforth referred to as "the *Framework*"), which laid out a vision for what science all students, regardless of background or location, should learn and know (National Research Council 2012). In this vision, students engage with natural phenomena using science and engineering practices to understand core ideas and crosscutting concepts in science. An emphasis on equitable instruction runs throughout the *Framework*.

During the last decade, the *Framework* has shaped reform efforts across all components of K–12 science education — including state standards, instructional materials, professional learning, assessments and accountability policies, instruction, and preservice teacher preparation. Ten years after its publication, it is still one of the most frequently downloaded reports from the National Academies Press (NASEM n.d.). Most notably, the *Framework* drove the development of the Next Generation Science Standards (NGSS; NGSS Lead States 2013).

How has the U.S. progressed toward the vision of science instruction captured in the *Framework*? This report describes the status of the field of K–12 science education, synthesizing data from multiple sources. We interviewed 50 stakeholders and surveyed over 350, including K–12 teachers, district and state science supervisors, and college and university faculty.[1] We also reviewed reports from NASEM about the components of science education in the U.S. Drawing on these sources, we comment on the field and how well developed each component is, making recommendations where appropriate.

1 Throughout this report, the survey is referred to as the *landscape survey*. More information about the study's methods is included in the appendix.

A Brief History of K–12 Science Education

A brief history illustrates how science education in the U.S. has changed — and stayed the same — over the last several decades.

The 1957 Sputnik launch initiated a transformation in K–12 science education (DeBoer 2014). As the federal government poured resources into putting a person on the moon, it also invested hundreds of millions in reforming K–12 science education to ensure the nation did not fall behind again. Congress passed the National Defense Education Act in 1958, which included an infusion of more than a billion dollars over four years (over $9 billion in 2022 dollars) to support undergraduate loans and scholarships, graduate fellowships, and a variety of curriculum projects and professional learning opportunities for secondary teachers that involved new ways of teaching in science, technology, engineering, and mathematics (STEM). The National Science Foundation (NSF) funded the development of science curricula designed to transform the way students learned science — from lectures, readings, and worksheets to hands-on activities where students interacted with materials and each other to solve problems. The goal was to make science learning much more like the work scientists do.

Unfortunately, for the most part, the new curricula did not take hold. Although the federal government invested heavily in curriculum development, the nation's decentralized education system constrained developers to a primarily "if you build it, they will come" approach. NSF funded opportunities for teachers to learn about the new curriculum materials, but whether due to lack of supply or lack of demand, the vast majority of science teachers did not participate. Neither did they use the curriculum materials widely. A notable exception was science teachers in grades 10–12, just over half of whom reported using one of the new curriculum materials in 1977 (Weiss 1978).

Additional efforts to reform elementary science instruction were made in the 1990s with the development of several new curricula that emphasized hands-on, inquiry-based science learning. However, by 2012, less than 10 percent of elementary science classes were using these materials. Most continued using traditional textbooks instead (Banilower et al. 2013). And although descendants of the NSF-funded curricula developed in the 1960s and 1970s persisted, they had all but disappeared from the landscape of instructional materials. A series of national studies of science education from 1977 to 2012 also documented little change in instructional strategies over that period.[2] Lecture and discussion continued to dominate, with students infrequently participating in science investigations.

2 See the National Survey of Science and Mathematics Education, available at horizon-research.com/NSSME/.

Near the end of the last century, state and national leaders recognized that for national reform to happen, there would need to be agreement on the science content students should learn and how to teach it. The 1990s saw two efforts to create national standards for K–12 science. The first was led by Project 2061 at the American Association for the Advancement of Science and resulted in *Benchmarks for Science Literacy* (American Association for the Advancement of Science 1993). The second was led by the National Research Council, culminating in the *National Science Education Standards* (National Research Council 1996). However, states had no incentives to adopt either document, and their uptake in state standards varied widely. Efforts to develop college- and career-readiness standards in other disciplines had more success. In 2010, with considerable financial incentives from the federal government, all but nine states adopted the Common Core State Standards (or Common Core) for English language arts (ELA) and mathematics.

Interestingly, and not unique to science, despite the lack of common standards in science, there was a de facto curriculum. Until the last decade or so, the textbook was still the most common form of instructional material. In attempts to maximize market share, publishers created science textbooks to meet the standards of the states with the largest populations and thus the greatest textbook demands (e.g., California, Florida, Texas, and New York). What resulted were encyclopedic textbooks that were widely used but included more content than students could reasonably learn in a school year. The amount of material encouraged lecture-style teaching at the expense of engaging students in science activities.

A national movement toward college- and career-readiness standards was tightly coupled with an accountability movement. Urged by federal incentives, states began to hold schools and school districts accountable for students' scores on state tests. These accountability measures focused primarily on ELA and mathematics, reflecting the nation's heavy investment in the 3Rs. To illustrate, federal incentives were (and still are) tied to school performance in both subjects in grades three through eight. States must test students in each grade to qualify for the incentives. In contrast, the federal government requires states to administer science tests only once in grades three through five, once in grades six through eight, and once in high school.

This brief history of K–12 science education brings us to 2012 and the publication of the *Framework*. The rest of the report focuses on progress toward the *Framework*'s vision over the last 10 years.

BRIDGESPAN'S FIELD-BUILDING FRAMEWORK

In 2022, Carnegie Corporation of New York commissioned Horizon Research, Inc. (HRI) to assess the progress of the field of K–12 science education in the United States since 2012, when the NASEM published *A Framework for K–12 Science Education* (referred to as "the *Framework*").

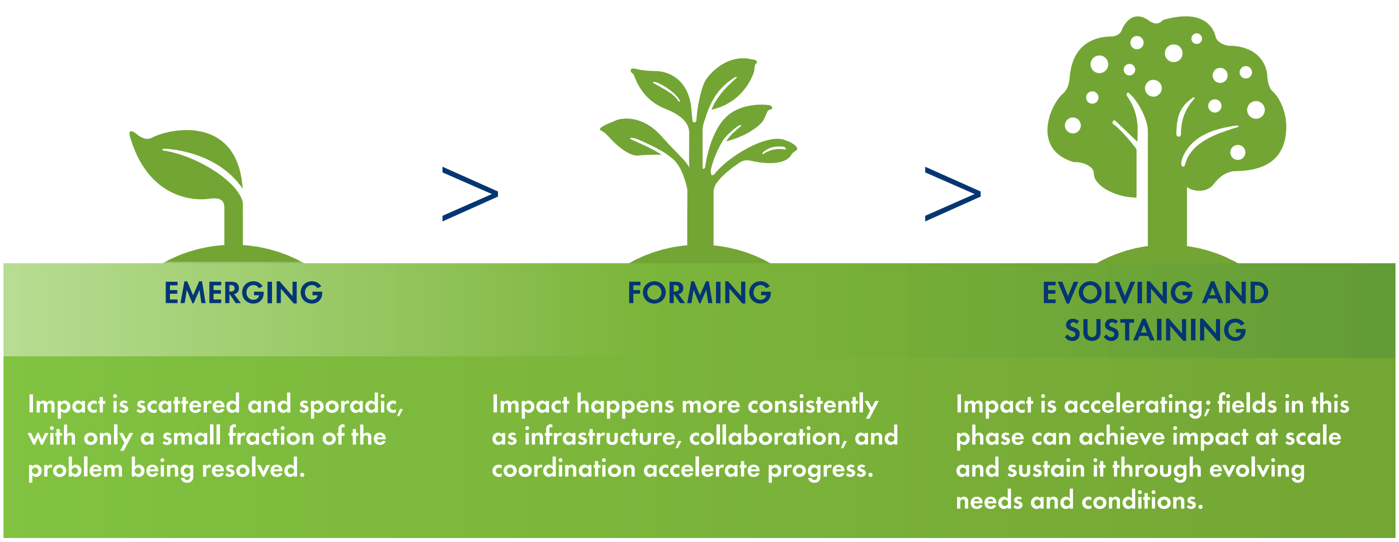
To study progress in the field of K–12 science education during the last decade, HRI adopted the Bridgespan Group's Field Building for Population-Level Change model (Farnham et al. 2020). The model evolved from Bridgespan's research in over 30 fields, including affordable housing, bail reform, and malaria eradication. Across these studies, Bridgespan identified five characteristics critical for building a field: a knowledge base, actors, a field-level agenda, infrastructure, and resources.

Bridgespan Group's Field Characteristics and Phases

1. **Knowledge base:** the body of academic and practical research that helps actors understand the problem, identify and analyze shared barriers to solving it, and develop solutions.
2. **Actors:** individuals and organizations that together bring a sense of shared identity and a common vision to the field.
3. **Field-level agenda:** a strategic suite of approaches that aims to address shared barriers and unlock collective progress.
4. **Infrastructure:** the supports that coordinate efforts and provide the "connective tissue" that strengthens each of the other four field characteristics and the complementarity between them.
5. **Resources:** financial and nonfinancial support for field-building efforts.

Farnham, Lija, Emma Nothmann, Zoe Tamaki, and Cora Daniels. 2020. *Field Building for Population-Level Change*. Boston: Bridgespan Group.

PHASES OF DEVELOPMENT



COMPONENTS OF THE K–12 SCIENCE EDUCATION FIELD

By many measures, the U.S. education system is one of the best in the world. It is also decentralized, complex, and resistant to change. Each state is autonomous, and although federal incentives create some uniformity across the nation, states have the ultimate decision-making power for education. Further, those who hold a stake in our education system are many and diverse, and they sometimes have competing interests. Stakeholders include families, teachers, and business and industry.

For this report, we define the field as formal K–12 science education in the U.S. (e.g., that occurring in schools, districts, and charter management systems) while acknowledging the important role of informal science initiatives, including museums, parks, and after-school activities. To understand the field of formal K–12 science education, it is important to understand the key components of K–12 education in the U.S., how they are tightly connected, and that stakeholders and states influence each one broadly. Too often, attempts to change one component ignore the others and, consequently, do not succeed. For example, efforts to improve teachers' skills without improving the instructional materials available to teachers are likely to be ineffective. We have defined six key components of the formal K–12 science education field. Brief descriptions of each follow.

State Standards

Each state adopts its own academic standards for ELA, mathematics, science, social studies, and other subjects. Standards take many forms, but they typically describe what students need to know and be able to do in each subject at each grade or grade band. Thus, they are powerful and intentional influences on what happens in classrooms. The standards landscape changed dramatically in 2010, when 41 states adopted new college- and career-readiness standards for ELA and mathematics. Although standards may vary across states, the nation remains largely unified around a goal of having standards to prepare all young people for success in college and careers.

Instructional Materials

Instructional materials (e.g., textbooks and web-based materials) are the tools teachers use to teach their subjects. Thirty years ago, commercially published textbooks were dominant, but in the 1990s, the internet changed the instructional materials landscape dramatically. Textbooks still have a strong foothold, but they increasingly compete with web-based materials, which take many forms. States vary in how much control they exert over the commercial instructional materials teachers have available. Some have elaborate adoption processes that make only certain materials available for purchase with state funds. Others give much more control to local education agencies. Within the noncommercial web-based domain, open educational resources (OER) — free and adaptable materials — are growing in availability and come in a wide variety of forms, from individual worksheets to full-course curricula.

Professional Learning

Teachers are required to participate in ongoing learning to stay current and hone their craft. State policies vary widely, but teachers must typically complete a certain number of hours of professional learning each year to retain their credential. Learning experiences take many forms, from independent study to workshops to college courses. A particularly prominent form is the professional learning community, in which teachers of the same grade or subject meet regularly and discuss their classroom practice — for example, through creating common lesson plans and analyzing student work. As discussed later in this report, curriculum-based professional learning, where experiences are anchored in learning to use new instructional materials, is becoming more prominent. Most decisions related to professional learning offerings are made at the school and district levels; however, the majority of states pool district resources to fund regional service providers that support schools and districts with planning and provide professional learning.

Instruction

All the components previously described are ultimately in the service of instruction, which still occurs primarily in classrooms. Teachers use a variety of instructional strategies, and while they differ somewhat by grade level, a few strategies tend to dominate. The pandemic temporarily disrupted in-person learning and dramatically changed the instructional practices teachers could use, but science teachers at all grade levels tend to rely heavily on lecture and discussion, typically in whole-class settings but also in small groups. Much less frequently, science teachers have their students do hands-on or laboratory activities, write about science, or work on long-term projects. Consequently, the field lacks widespread examples of the kind of science instruction the *Framework* envisions, where students build their understanding of science concepts by using science and engineering practices to study natural phenomena.

Assessments and Accountability

States develop their own subject-specific student assessments and accountability systems. Ideally, assessments align closely with state standards, sending a consistent message to teachers about what they should teach. States typically administer assessments at the end of the school year, but there is wide variation in how they use test scores for accountability. In many states, the scores factor into decisions about student promotion and teacher evaluation. States also use the scores to compare schools and districts to identify ones that are successful and remediate those that are not. For all these reasons, state tests and accountability systems — like state standards — powerfully influence what is taught and how it is taught.

Preservice Teacher Preparation

How teachers are prepared and credentialed has changed dramatically in recent years. Not too long ago, the vast majority of teachers opted for preparation in a college- or university-based undergraduate degree program leading to a credential. In the last 20 years, the number of pathways to the classroom has increased for those without a teaching credential who have a bachelor's degree in a field other than education. The pathways include:

- Lateral entry — individuals begin teaching immediately, typically affiliating with a college or university to complete coursework toward a credential while they are teaching.
- Graduate certification — individuals enroll in a graduate program and take courses toward a credential, often a master's degree, within a couple of years.
- Residency programs — individuals complete a yearlong, school-based residency during which they take courses toward their credential and apprentice with a classroom teacher, taking on increasing classroom responsibilities.

K–12 SCIENCE EDUCATION IN 2022

It is important to acknowledge that science education is given a lower overall priority relative to ELA and mathematics in the U.S. K–12 education system. The status of science education is particularly apparent in state and federal accountability policies, as described later in this report. It was also a prominent theme in comments from those who answered the landscape survey and individuals interviewed for this study, many of whom argued forcefully that until policymakers and society broadly elevate the importance of science as a school subject, work within the field to bring about standards-aligned science instruction will have limited impact.

> *A policy issue that pops up all the time . . . is the question of priority. Many, many people will trace it to accountability changes that happened as a result of the initial No Child Left Behind Act that focused districts on literacy and math in a certain way and prioritized certain forms of assessment. And even though some of those things have faded or shifted in the policy world, it hasn't really faded or shifted in practice. I don't know what the answer is . . . but something about that policy sent a message about what's the priority in schooling, where often I walk into schools, and science is scheduled as a special, [the same way] kids might get an art class once a week, but that's also what would be expendable.*
>
> – Preservice teacher educator

This view resonates with the recent report *Call to Action for Science Education: Building Opportunity for the Future* (National Academies of Sciences, Engineering, and Medicine 2021a). The report makes a case for why better, more equitable science education should be a national priority and offers a vision and guidance to achieve it.

State Standards

Among the interrelated components of the education system, state standards are perhaps the most important. They define the vision that all other components must align with for the field to move forward. As recently as 2013, each state had its own science standards, but as states were adopting new college- and career-readiness standards in ELA and mathematics, work was also underway to create a parallel set of standards in science. The *Framework* and the NGSS draw on a substantial knowledge base. In 2009, Carnegie Corporation of New York funded the Board on Science Education at NASEM to provide a vision and purpose for science education. The financial resources the Corporation provided were essential for initiating the work. The Board on Science Education provided critical infrastructure through a series of convenings where national experts and stakeholders discussed the vision. This work led to the 2012 publication of the *Framework*, which describes science learning where students use science and engineering practices to study natural phenomena (e.g., plants growing, weather changing, light reflecting) and build an understanding of core science ideas and overarching concepts.

Using the *Framework* as a blueprint, Achieve, a nonprofit education reform organization whose mission included working with states to raise academic standards,[3] facilitated the development of the NGSS with funding from Carnegie Corporation of New York. Achieve partnered with 26 lead states (Arizona, Arkansas, California, Delaware, Georgia, Illinois, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Jersey, New York, North Carolina, Ohio, Oregon, Rhode Island, South Dakota, Tennessee, Vermont, Washington, and West Virginia) as co-developers of the NGSS. Even the name of the published document — *Next Generation Science Standards: For States, by States* (NGSS Lead States 2013) — points to the importance of state-level

3 Achieve was active from 1996 to 2020, when the work transitioned to WestEd's NextGenScience.

involvement and ownership. The strategy effectively created a field-level agenda for standards adoption and drew many actors with vision and decision-making authority into the work. Many lead states adopted the NGSS within two years of publication, and several others did so in subsequent years.

Whereas federal incentives drove the adoption of the Common Core standards, states came to the NGSS in their own time (and without incentives), with substantial behind-the-scenes work building support. For example, Carnegie Corporation of New York funded convenings of professional organizations and school district leaders to discuss the NGSS. The Corporation also funded messaging campaigns to build awareness of the new standards. Over the last 10 years, 48 states plus the District of Columbia have adopted the NGSS or science standards influenced by the *Framework* and the NGSS.

Status of State Standards

After a decade of sustained effort, almost all states share a vision of science instruction at the level of standards, which is a crucial first step for field-level reform. The work benefited from a robust knowledge base, knowledgeable and influential actors, a field-level agenda, infrastructure, and resources. ***State standards are thus in the evolving and sustaining phase of development***. The words “evolving” and “sustaining” are key. State standards are not permanent. They are subject to change at the discretion of state legislatures, and although the NGSS enjoy broad support, it is not guaranteed in the long term. Changes to state standards are inevitable. What is important is that those changes are consistent with the vision of the *Framework*. In time, the NGSS themselves may need to change. Fortunately, when Achieve closed its doors in 2020, it assigned the NGSS copyright to NASEM, which published the *Framework*. The Board on Science Education at NASEM is well positioned to convene stakeholders, such as members of the Council of State Science Supervisors, to discuss changes to science standards and offer guidance to states on making *Framework*-aligned changes to states’ standards.

TABLE 1

	PHASE		
Field Characteristics	**Emerging**	**Forming**	**Evolving and Sustaining**
Knowledge Base			●
Actors			●
Field-Level Agenda			●
Infrastructure			●
Resources			●
Overall Status			●

Instructional Materials

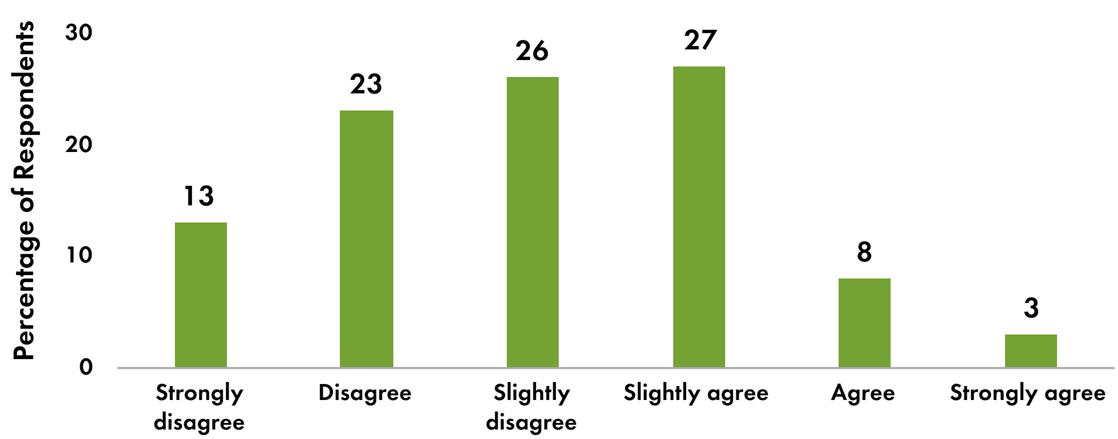
State standards are essential for an aligned, coherent system. They describe what students need to know, understand, and be able to do by the end of each grade and course. However, state standards do not dictate how to get students to the goals they describe. Ultimately, that is the job of the professionals in the classroom — teachers. Teachers, in turn, rely heavily on instructional materials, including traditional options, such as printed textbooks and worksheets, and newer options, such as OER that are online, freely available, full-course instructional materials teachers can adapt for their contexts. Well-designed, high-quality instructional materials are critical for moving the field toward the vision of standards-aligned instruction in all classrooms.

The field has not yet reached a consensus on whether teachers should create their own instructional materials. Most landscape survey respondents (62 percent) said teachers should not be expected to do so (see Figure 1). Others argued that creating one's own materials is the mark of a professional. For example, preservice teachers are often expected to demonstrate their readiness for the profession by creating or assembling their own instructional resources. The argument for putting high-quality materials in teachers' hands supports the idea that teachers deserve higher-quality, more customizable curriculum options that are aligned with a state's academic standards. Equipping teachers with the best evidence-based tools available will help them personalize instruction and meet the needs of each student. Such instructional materials, accompanied by aligned, high-quality professional learning and assessments, can support teachers to be successful professionals.

Curriculum developers benefit from a strong knowledge base about how students learn and what standards-aligned instruction should look like (see box, p. 18). Those trying to develop instructional materials aligned with the NGSS have another important asset — the Educators Evaluating the Quality of Instructional

FIGURE 1

Survey Respondents' Opinions about Teachers Creating Their Own Materials



Note: Figure shows responses to a survey item that read: "Teachers should try to develop their own NGSS-aligned instructional materials rather than use or adapt published NGSS-aligned instructional materials." *N* = 354.

Products (EQuIP) Rubric for Science (Next Generation Science Standards 2021) and accompanying review process for instructional units. The EQuIP rubric was developed by Achieve, with the review work now being sustained by WestEd through its NextGenScience project.[4] Specially trained peer-review panels, made up of classroom teachers and educators with classroom teaching experience, use rubric criteria to assess the alignment of individual instructional units with the NGSS and give detailed feedback to developers. The rubric is also available for free on the NextGenScience website, allowing instructional materials developers to use the criteria for guidance.

Knowledge Base Informing K–12 Science Education

The following studies synthesize the literature on learning and implications for teaching science:

- *How People Learn: Brain, Mind, Experience, and School* (Bransford et al. 1999)
- *How Students Learn: Science in the Classroom* (National Research Council 2005)
- *How People Learn II: Learners, Contexts, and Cultures* (NASEM 2018)
- *Science and Engineering for Grades 6–12: Investigation and Design at the Center* (NASEM 2019)
- *Science and Engineering in Preschool through Elementary Grades: The Brilliance of Children and the Strengths of Educators* (NASEM 2021b)

Another source of instructional materials reviews is the EdReports website, which aims to help district leaders identify high-quality instructional materials. EdReports began by providing reviews of ELA and mathematics instructional materials and has more recently added reviews of science instructional materials. In contrast to EQuIP, EdReports reviews full-course instructional materials (as opposed to individual units). Like EQuIP, EdReports employs educator-led review teams and detailed criteria to determine its ratings. Reviewers assess materials through three review criteria: alignment to the NGSS, coherence and scope, and instructional supports and usability. Both NextGenScience and EdReports represent important actors in the field.

> *I think there's a diversity of approaches [among curriculum developers], but there's a commonality in the belief around how students should learn science. Even if you're using [the] 5E [instructional model] or [a] storylines [approach] or another method, the students should be the ones answering their own questions rather than the students solely answering the questions that the teacher poses.*
>
> – Curriculum development leader

Currently, the presence of high-quality, NGSS-aligned instructional materials in science classrooms is limited due to their small supply and district and state textbook adoption policies. Because the supply is limited, districts in many states have not prioritized science curriculum adoption for years. But policies have the power to change science instruction at scale by placing instructional materials in all district classrooms. Consequently, when districts restart their adoptions or revise their policies, it is essential that they have high-quality K–12 science instructional materials to choose from.

4 The highest-rated units receive the NGSS Design Badge. NextGenScience.org provides the public with free access to lessons and units that have earned the badge.

Some school districts have stopped purchasing materials and are instead creating their own or asking teachers to do so. Given the increase in freely available OER materials (Bellwether Education Partners 2020), many school districts expect teachers to find materials themselves. A recent study found that 62 percent of middle school teachers and 84 percent of high school teachers routinely used science materials they created (Doan et al. 2021), making these the most common type of materials used. More than half of teachers reported using YouTube and the Teachers Pay Teachers website to supplement their materials. In addition, the materials most commonly *required* by schools and districts were those *created* by schools and districts.

The development of NGSS-aligned materials has accelerated in the last few years, largely due to the launch of OpenSciEd in 2018. The initiative set out to create a comprehensive set of instructional materials and professional learning resources for middle grades science that would be freely available in multiple digital formats, including print-ready and editable. That mission was accomplished early in 2022 when full-course materials were publicly released for the middle grades. All 18 OpenSciEd units for grades six through eight received exemplary ratings on the EQuIP rubric, and the full middle school program is now under review by EdReports. As a result, U.S. schools have free access to high-quality science materials in these grades, and over 40,000 educators have registered on the OpenSciEd website to access them. OpenSciEd materials are not the only ones receiving high ratings. EdReports has rated one yearlong commercial middle grades curriculum (Amplify Science) as meeting NGSS expectations.

Materials are improving, and I think five years from now, we will have a K–5 and a middle school and a high school material solution for teachers that is high-quality and districts can consider.

– Instructional materials expert

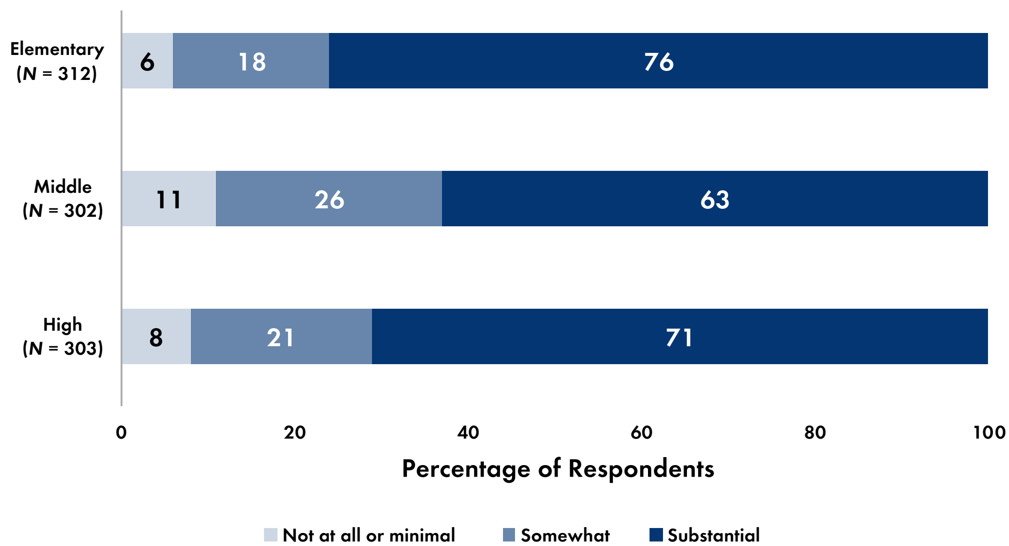
OpenSciEd began developing high school instructional materials in January 2020 and field-testing them in September 2021. The development of materials for elementary grades began in September 2022. In addition, OpenSciEd has partnered with several commercial entities (also important actors) that both create derivative products from the OER materials and supply packaged kits of consumable and nonconsumable supplies to accompany the instructional units, increasing the flexibility with which schools can adopt and implement the units. Further, because OpenSciEd units are open-source, states, districts, and schools can adapt them for their local contexts. Of course, this flexibility also creates the potential for adaptations that compromise the materials' quality.

Despite increased development efforts, NGSS-aligned instructional materials for elementary and high school classrooms are still lacking. Only four units at each level have received EQuIP Design Badges. These units typically last a few weeks and are not meant for an entire school year. In addition, they are not available for all grades and subjects, so teachers must use other materials that are likely not NGSS-aligned to fill in the gaps. Among landscape survey respondents, more than 60 percent said there is a substantial need[5] to change instructional materials to make them more aligned with the NGSS (see Figure 2). Opinions about progress varied by grade range, with the most positive assessments in the middle grades, followed by high school and elementary (see Figure 3).

5 Gave a rating of 4 or 5 on a scale from 1 (not at all) to 5 (to a great extent).

FIGURE 2

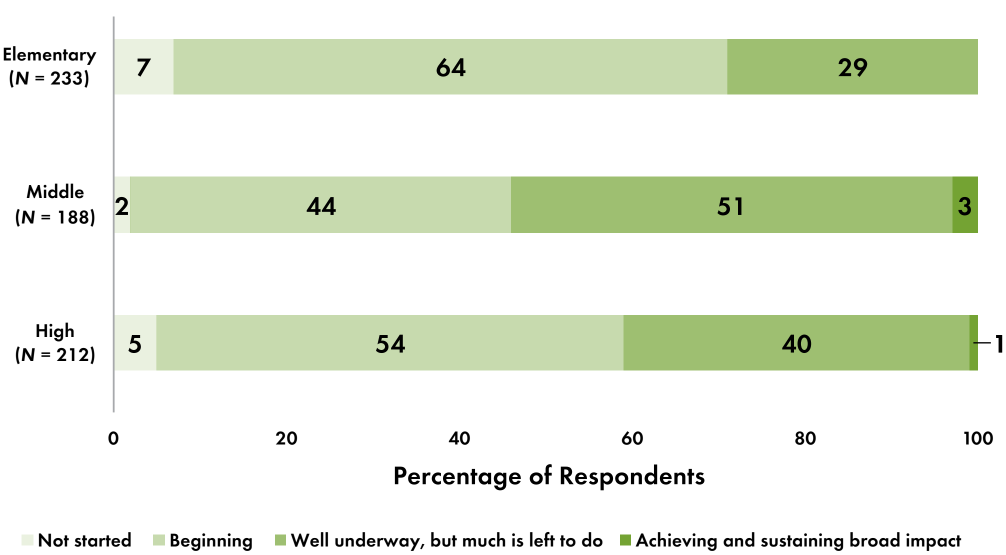
Need for Change: Instructional Materials



Note: Figure excludes those who responded, "I don't know."

FIGURE 3

Progress of Work toward Needed Changes: Instructional Materials



Note: Only those who indicated a substantial need for change saw this survey item.

The infrastructure for instructional materials development is complex. Textbook publishers, which have traditionally provided development infrastructure, have not invested in creating NGSS-aligned materials. In contrast, OpenSciEd has created a consortium of developers for instructional materials at the elementary, middle, and high school levels. Each consortium consists of multiple organizations and multiple individuals within each organization. These consortia work closely with a group of 10 states (the state steering committee) to ensure teachers' and schools' needs are addressed. These partner states have recruited hundreds of teachers to field-test OpenSciEd instructional materials with thousands of students and provide feedback to guide revisions before the materials are publicly released. Field-testing has the added bonus of creating interest in and demand for OpenSciEd instructional materials in partner states and others through word of mouth. Through regular convenings and ongoing meetings, OpenSciEd's work, along with other efforts, is building capacity in the nation for instructional materials development. Although this strategy does not rise to the level of a field-level agenda, it is a model with a track record of generating high-quality instructional materials.

OpenSciEd brought states to the table, [and it] has been wonderful to have the states providing the revision and the direction of the materials. And I think that's been strong work that I hope will be replicated across the system.

– Curriculum development leader

Work on NGSS-aligned instructional materials has received little public funding. NSF stopped awarding grants in its Instructional Materials Development program, which funded the development of full-course curricula, several years ago. In contrast, private foundations have invested heavily. Carnegie Corporation of New York began offering funding for the OpenSciEd middle school materials and was joined by several other national foundations, most of which have continued to support elementary and high school curriculum development. Among the foundations backing the development of science instructional materials are the Bill & Melinda Gates Foundation, the Charles and Lynn Schusterman Family Philanthropies, the Walton Family Foundation, and the William and Flora Hewlett Foundation. To date, OpenSciEd has received about $35 million toward its work, representing considerable resources for high-quality K–12 science instructional materials.

Status of Instructional Materials

Thanks largely to reports commissioned by NASEM, the field has a robust knowledge base for creating standards-aligned instructional materials. The group of actors (both individuals and organizations) developing materials and supporting their dissemination is growing, providing districts with some options to choose from and ways to determine the quality of the instructional materials. OpenSciEd is leading the charge on development work, but many others are active, creating individual units and entire courses. Still, there is room for additional actors. OpenSciEd's development and dissemination strategy, which includes broad consortia of developers and heavy involvement from partner states, teachers, and students, has the potential to become a field-level agenda. This approach has been effective in ensuring rigorous development. It is also intended to create demand for high-quality science instructional materials in these partner states (and ideally others like the Council of Chief State School Officers' Instructional Materials and Professional Development Network of 13 states), though the effectiveness of this strategy remains to be determined. Infrastructure for instructional materials development is growing, but it is largely specific to individual efforts. More will be necessary to meet the field's need for materials. Finally, the development of high-quality, standards-aligned instructional materials has benefited from substantial financial resources donated by private foundations. Again, much work remains, and more resources will be needed. ***For these reasons, instructional materials are in the forming phase***.

TABLE 2

	PHASE		
Field Characteristics	**Emerging**	**Forming**	**Evolving and Sustaining**
Knowledge Base			●
Actors		●	
Field-Level Agenda		●	
Infrastructure		●	
Resources		●	
Overall Status		○	

Professional Learning

Current science standards in almost all states emphasize students doing the work of science to learn science concepts. That means students should ask questions, design investigations, analyze and interpret data, solve problems, and communicate their solutions as part of their science learning. Because this kind of instruction contrasts so sharply with what happens in most science classrooms, teachers need ongoing professional learning opportunities to understand the standards and implement them in their classrooms.

Fortunately, the field has a substantial knowledge base about what constitutes good professional learning, which is synthesized in *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts* (NASEM 2015). From this work, five principles of professional learning for teachers of all subjects emerged:

- **Content focus:** Learning opportunities for teachers focus on subject matter content and how students learn that content.
- **Active learning:** Teachers are active participants rather than passive recipients, engaging in such activities as observing expert teachers (followed by interactive feedback and discussion), reviewing student work, and leading discussions.
- **Coherence:** Opportunities are consistent with other learning experiences and with school, district, and state policy.
- **Sufficient duration:** Both the total number of hours and the span of time over which the hours take place are sufficient.
- **Collective participation:** Teachers participate with others from the same school, grade, or department.

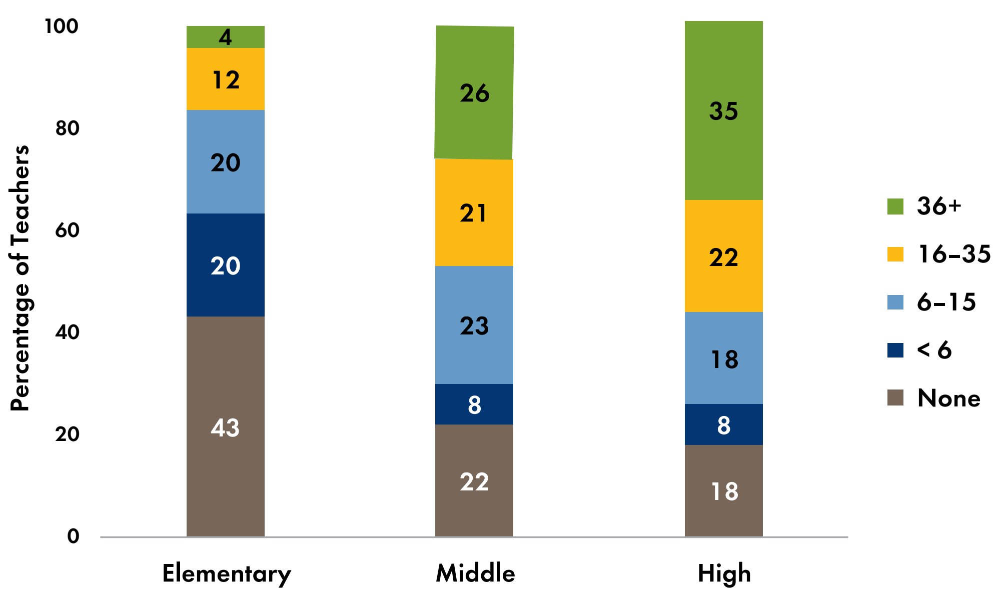
Given the importance of high-quality instructional materials, some have suggested another component to this consensus model — learning experiences for educators that mirror their students' experiences with curriculum. Carnegie Corporation of New York released a report in 2020 titled *The Elements: Transforming Teaching through Curriculum-Based Professional Learning* offering a framework for designing and implementing curriculum-based professional learning anchored in the use of high-quality instructional materials (Short and Hirsh 2020). Recent reports highlight the potential of professional learning anchored in the use of curriculum but stress how much work remains for the approach to become widely acknowledged and used (Chu et al. 2022; Hill and Papay 2022). It should also be noted that OpenSciEd is creating and field-testing extensive professional learning materials along with instructional materials. These professional learning materials include guidelines for planning, enacting, and reflecting on instruction. They also include facilitated experiences for each unit to familiarize teachers with the details of the unit and the OpenSciEd pedagogical approach. The professional learning materials created for the program, like the instructional materials themselves, are freely available on the OpenSciEd website. However, despite the knowledge base and emerging models for professional learning (like curriculum-based professional learning), the field lacks a common agenda for advancing opportunities for teachers. Curriculum-based professional learning has the potential to shape that agenda.

Organizations at all levels, from local to national, are involved in providing professional learning, but it is not clear that they are all actors in terms of bringing about needed changes. More than half of landscape survey respondents rated the leadership for reforming professional learning as inadequate. Without a field-level agenda to unify them, it is not clear that the efforts of national organizations, regional service providers, and local school district curriculum supervisors will converge. Stakeholders acknowledged in interviews that in some school districts, science teachers have standards-aligned opportunities, but nationally, the status of professional learning for K–12 science teachers runs counter to the field's knowledge base. Perhaps the most obvious contradiction is in the small amount of time science teachers spend on science-specific professional learning. The most recent national data indicates that 43 percent of elementary teachers participated in no science-specific professional learning in the previous three years (see Figure 4; Banilower et al. 2018). Among high school teachers, the picture is better, but still only about a third participated in more than 36 hours of professional learning in the same time frame.

> *We're starting to see some [instructional] materials I think at all the levels, more so at the middle school and elementary levels than at the high school, but there's getting to be some stuff that's out there. But those materials aren't going to ever be useful unless teachers have really strong professional learning. I mean, materials are just that; they're just materials, but unless teachers really know how to implement them, it's not going to go anywhere.*
>
> – Science education researcher

FIGURE 4

Hours Spent in Science Professional Learning in the Last Three Years



Banilower, Eric R., P. Sean Smith, Kristen A. Malzahn, Courtney L. Plumley, Evelyn M. Gordon, and Meredith L. Hayes. 2018. *Report of the 2018 NSSME+*. Chapel Hill, NC: Horizon Research, Inc.

> *One challenge is getting teachers access to professional learning. Not all districts are able to support the cost, including travel and [substitute teacher] coverage, for teachers to participate when these opportunities are offered during the school day. When these opportunities are offered outside of the school day, a lot of teachers do not have the capacity to participate or attend.*
>
> – Classroom teacher

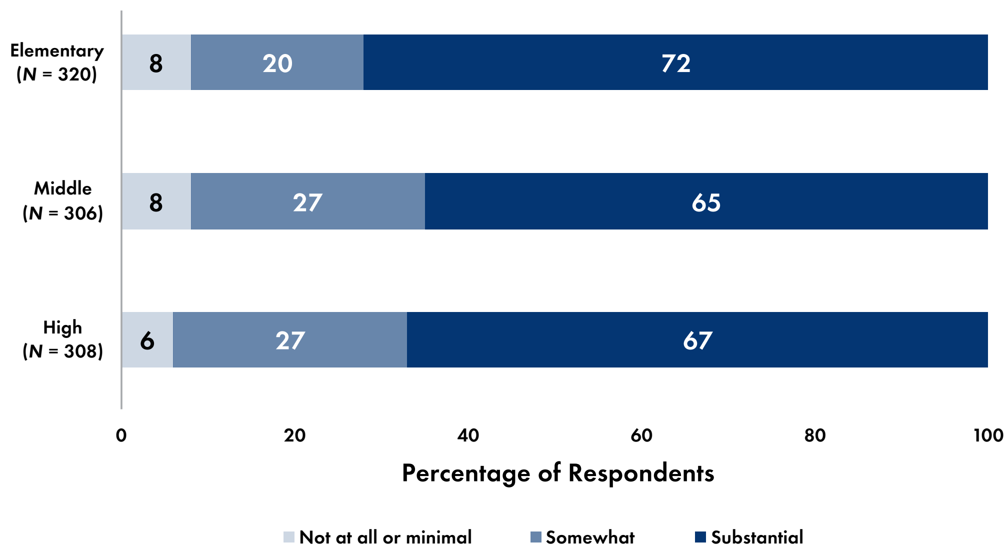
Data on the availability and quality of professional learning opportunities is similarly discouraging. One national survey found that fewer than half of U.S. schools offered any science-specific professional learning opportunities in the preceding three years (Banilower et al. 2018). Fewer than half of science teachers in that study reported that their professional learning opportunities allow them to experience instruction as their students would, and only about a third said their professional learning emphasized implementing the instructional materials used in their classrooms (Banilower et al. 2018). Less than a quarter of landscape survey respondents agreed[6] that science teachers have enough professional learning opportunities to learn to use high-quality, NGSS-aligned instructional materials. More than two-thirds saw a substantial need to change the design of professional learning to better prepare teachers for *Framework*-aligned science instruction (see Figure 5), and most saw the work of change as either not having started or just beginning (see Figure 6).

More promising is the presence of national convening organizations for conversations about this work. The National Science Teaching Association (NSTA) hosts national conferences and offers free webinars and other opportunities for educators to come together and learn about standards-aligned instruction. The National Science Education Leadership Association (NSELA) provides virtual and in-person meetings for those tasked with supporting science teachers through professional learning. The Association for Science Teacher Education (ASTE) supports professional learning for in-service science teachers in addition to preservice teacher preparation. These organizations provide an infrastructure for advancing professional learning, but the lack of a field-level agenda constrains progress. And the Council of State Science Supervisors (CSSS) developed a set of *Science Professional Learning Standards* to provide guidance to state and local leaders.

6 Gave a rating of 4 or higher on a scale from 1 (strongly disagree) to 6 (strongly agree).

FIGURE 5

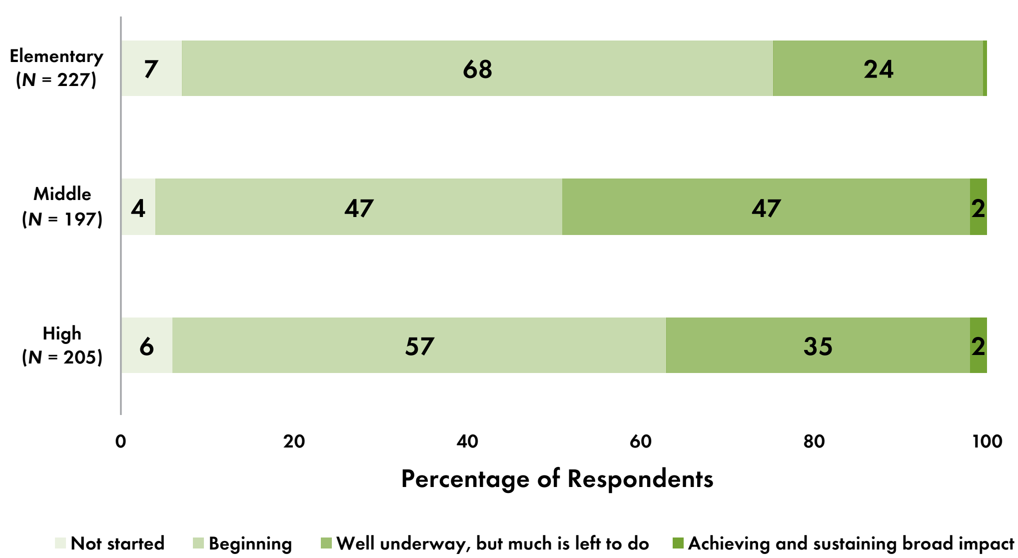
Need for Change: Professional Learning



Note: Figure excludes those who responded, "I don't know."

FIGURE 6

Progress of Work toward Needed Changes: Professional Learning



Note: Only those who indicated a substantial need for change saw this item.

Status of Professional Learning

Professional learning for standards-aligned science instruction has a robust knowledge base and a growing number of models that reflect that knowledge. However, these have not yet coalesced into a field-level agenda. And although the field of professional learning has many players at all levels, it is not clear that it has enough actors contributing to field building. The field has some infrastructure through organizations such as ASTE, CSSS, NSELA, and NSTA that support professional learning for science teachers, but again, a field-level agenda for improving professional learning is lacking. Nationally, science teachers lack widespread opportunities for professional learning and time to participate, reflecting reluctance at the district, state, and national levels to prioritize and provide resources for professional learning for science teachers. ***For these reasons, professional learning is in the emerging phase***.

TABLE 3

	PHASE		
Field Characteristics	Emerging	Forming	Evolving and Sustaining
Knowledge Base			●
Actors	●		
Field-Level Agenda	●		
Infrastructure		●	
Resources	●		
Overall Status	●		

Instruction

In standards-aligned instruction, students learn by using science and engineering practices to explain natural phenomena, design solutions to problems, and apply core science ideas and crosscutting concepts. Our interviews with stakeholders began by asking them to describe the status of science instruction compared with 10 years ago, just before the *Framework* was published. All saw progress toward the vision in the *Framework*, but most also saw considerable work to be done.

Those who described differences in progress by grade range consistently put middle grades in front of elementary and high school, largely due to the growing availability of high-quality, standards-aligned instructional materials, along with professional learning opportunities linked to those materials. Landscape survey results support this conclusion. More than two-thirds of respondents saw a substantial need[7] to improve science instruction at all levels to better align with the vision of the *Framework* (see Figure 7). Of these, most indicated the work has not started or is just beginning at the elementary and high school levels, with a somewhat more positive assessment in the middle grades (see Figure 8).

Reports from teachers also suggest the opportunity for standards-aligned instruction is not consistently present in most U.S. classrooms. For example, in the elementary grades, students receive less than half the instruction in science they receive in mathematics and less than one-third the instruction they receive in ELA (Plumley 2019). In addition, across grades K–12, students do not consistently experience science instruction where they do the work of science to learn science concepts (e.g., analyze and interpret data, make claims about phenomena) and instead spend time listening to lectures or reading textbooks (Banilower et al. 2018).

Although much work remains, the field is poised for progress due to several assets. First, the knowledge base about what standards-aligned science instruction looks like is strong, due in large part to the NASEM reports (see box, p. 18). In addition, the field has many actors — organizations and individuals leading efforts to align classroom instruction with new science standards.

One challenge is that the number of teachers of science is extremely large. According to the National Center for Education Statistics (2021), there are approximately 1.8 million elementary teachers alone, the majority of whom are supposed to teach science. When also factoring in middle and high school, the total number of science teachers in the U.S. is closer to two million. The magnitude of the need to change science instruction may explain why almost two-thirds of landscape survey respondents rated leadership for reforming classroom instruction as inadequate. Some stakeholders commented on leadership as well in interviews.

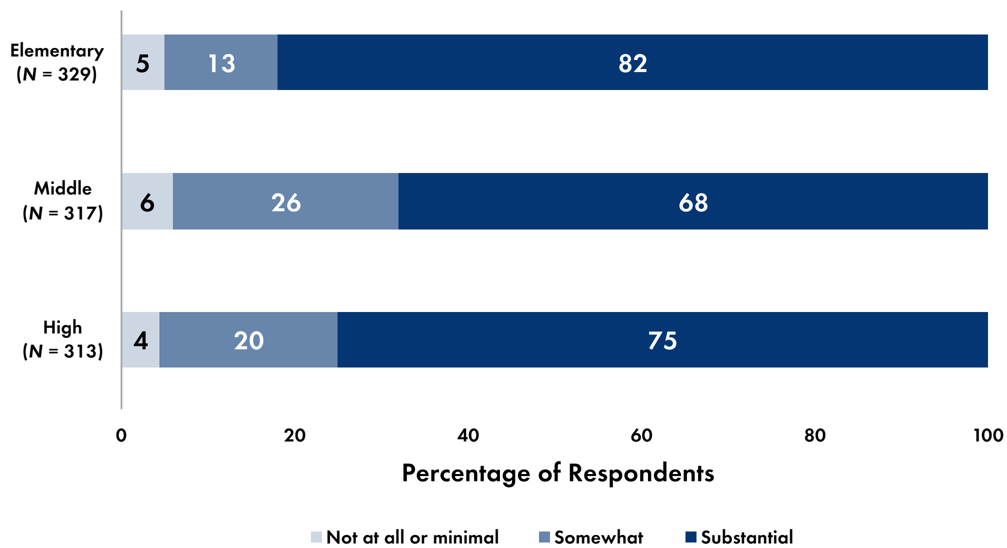
> *We just don't have enough hands. And then we don't have enough people in kind of driver positions that really understand the importance of science education.*
>
> – State leader

Interviews with stakeholders suggest a field-level agenda is taking shape and garnering support. The agenda seems to rely on two strategies: professional learning and instructional materials. Some stakeholders discussed these separately, while others described them as working in tandem, consistent with the curriculum-based professional learning model discussed in the previous section. Still others mentioned reforming state assessments and preservice teacher preparation, underscoring the need to align all components of the system.

7 Gave a rating of 4 or 5 on a scale from 1 (not at all) to 5 (to a great extent).

FIGURE 7

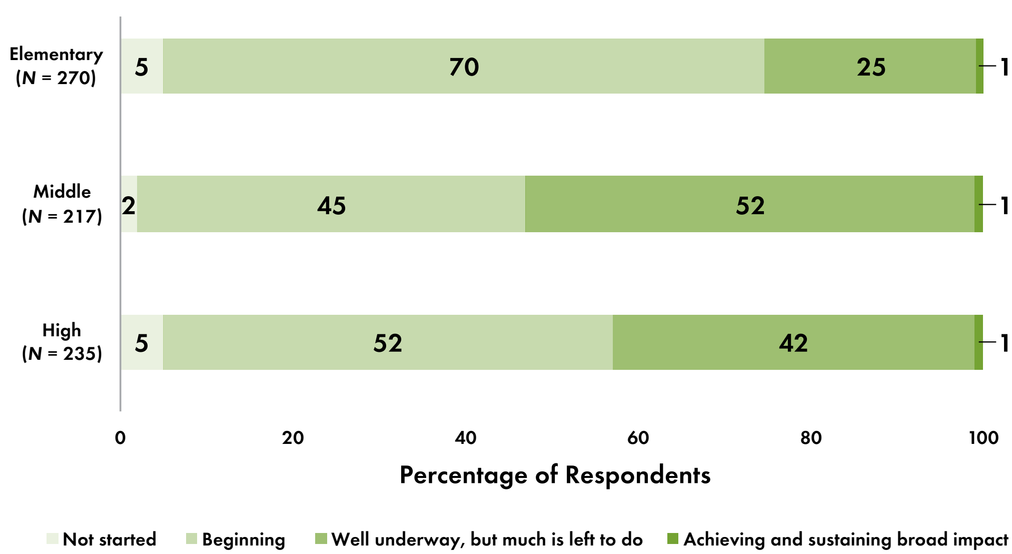
Need for Change: Instruction



Note: Figure excludes those who responded, "I don't know."

FIGURE 8

Progress of Work toward Needed Changes: Instruction



Note: Only those who indicated a substantial need for change saw this item.

Commitment to the integration of high-quality curriculum materials and high-quality professional learning [is needed]. That districts make the commitment for teachers to spend the time. Not add two hours onto the end of my already-long professional day but create experiences that align with the research on professional learning, where, for example, there's a deep dive in the summer, and then we have professional learning communities during the school year, and we keep it up for years, not three days before school begins.

– Science education researcher

The field also benefits from its infrastructure, in large part due to NSTA, which hosts national conferences and webinars where science teachers and science education experts share ideas about best practices. Further, each state has its own NSTA affiliate, and these host their own annual meetings, as well as other convenings. CSSS and NSELA also provide important infrastructure through their annual meetings and online convenings. More than eight in 10 landscape survey respondents said formal structures exist for sharing ideas about standards-aligned science instruction, and two-thirds of those rated the structures as adequate or better.

Although there is infrastructure at the state and national levels for science education leaders, most classroom teachers do not attend these convenings. This is especially true of elementary teachers, who often do not think of themselves as science teachers. More infrastructure is needed at the local level — such as science coaches, materials centers, and regional support centers — to help teachers understand new science standards and implement new science instructional materials.

In addition to the lack of local infrastructure, almost eight in 10 survey respondents rated the level of funding for reforming science instruction as inadequate, perhaps reflecting the overall low priority given to science instruction in K–12 education. This lack of resources hinders progress toward the vision of standards-aligned instruction in all classrooms.

Status of Instruction

Data from stakeholder interviews, the landscape survey, and national surveys of teachers suggests that science instruction generally does not align well with the vision laid out in the *Framework*, though some schools and districts are well out in front of the rest of the field. A strong knowledge base positions the field well for progress, as does a growing consensus regarding a field-level agenda. However, while there are many actors leading reform efforts, the magnitude of the field's need outstrips their capacity. National science teaching organizations offer some infrastructure, but more accessible, local options are needed to impact the majority of classroom teachers. In addition, according to stakeholders, the financial resources available for reform are inadequate. ***For these reasons, instruction is in the emerging phase***.

TABLE 4

	PHASE		
Field Characteristics	**Emerging**	**Forming**	**Evolving and Sustaining**
Knowledge Base			●
Actors	●		
Field-Level Agenda		●	
Infrastructure		●	
Resources	●		
Overall Status	●		

Assessments and Accountability

In the U.S., school performance is measured at least in part through state-administered tests. Many states use these same measures to evaluate teacher performance, and some use them to evaluate students. Consequently, like state standards, state assessments strongly influence what happens in classrooms — both what is taught and how it is taught.

Accountability pressures are most prominent in ELA and mathematics. As described earlier, the federal government requires testing in ELA and mathematics in each of grades three through eight and once in high school. But science testing is required only once in each of three grade ranges: 3–5, 6–9, and 10–12. Most states administer science assessments at the end of grades five and eight and at the end of a high school biology course. Unlike scores in ELA and mathematics, science test scores are not required by federal legislation to be included when evaluating school performance. As a result, only 27 states include science scores in their accountability systems (Achieve 2019).

In aligned systems, assessments closely mirror state standards, but when standards change, assessments tend to lag behind because developing new ones is expensive and time-consuming. The lag can result in a system that is misaligned, leaving teachers with mixed messages about what to teach. Because so many states have adopted the NGSS or science standards influenced by the *Framework* and the NGSS in recent years, the potential for misalignment is substantial.

> *If what we claim matters about student learning — and what plain matters about the nature of the content — is important, our assessments need to be aligned with those. And I think too often we do the reverse — "Here's the high-stakes test. Teach to that test." If the test is brilliant, then great. Let's teach to it. But if it's the model that we measure what's easy to measure instead of what's important to measure, then teaching to the test is not necessarily a good thing.*
>
> – Science education researcher

Further, stakeholders do not agree on whether the field would benefit from all states including science in their accountability systems. Some argue for it, reasoning that such a shift would lead to more resources and instructional time for science.

> *State Departments of Education should act now to include science in their accountability systems for K–12 education. A state accountability system for science needs to include assessments that support classroom instruction, assessments that monitor science learning more broadly (at the school, district, and state levels), and indicators that track the availability of high-quality science learning opportunities.*
>
> – NASEM (2021a, 9)

Others are wary, citing potential negative effects on students and concerns about how well state assessments align with the *Framework*, among other reasons.

> *We will not get the assessments and tests we need if we ask to be part of that system. We will get the same tests that we're getting from the vendors today. I think we have to eliminate the high-stakes testing that gives vendors an outsized role in defining what assessments look like.*
>
> – Science education researcher

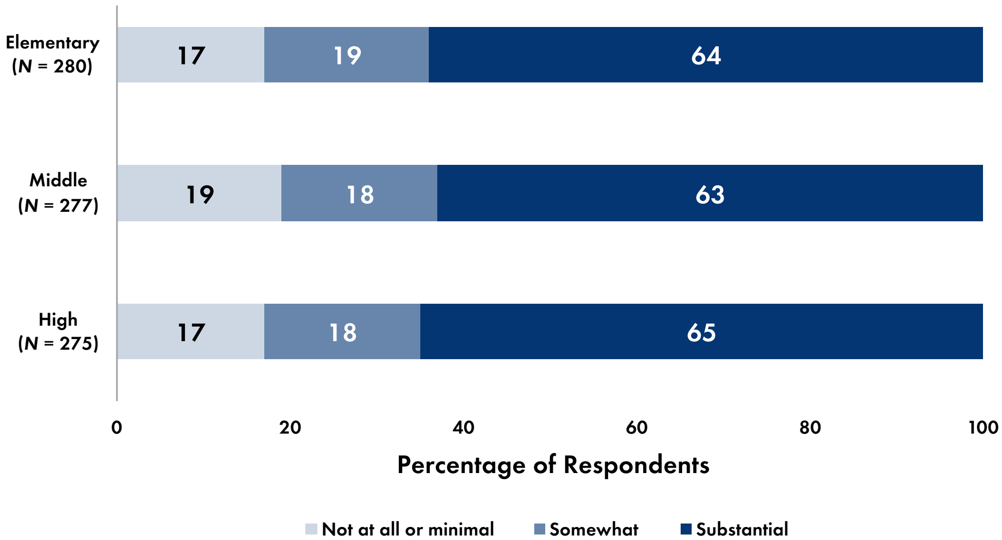
There is no authoritative data on the extent of alignment between state tests and state standards in science. However, among the 48 states that have adopted the NGSS or standards influenced by the NGSS, the vast majority of state assessment websites claim that their science assessments align with their standards. Landscape survey results offer a contrasting view. Less than 40 percent of respondents said the assessment and accountability policies in their state substantially support *Framework*-aligned science instruction. Further, nearly two-thirds said there is a substantial need to change their state's science assessments to better align with the *Framework* (see Figure 9). Roughly two-thirds of respondents who indicated a need for change said the work either has not started or is just beginning (see Figure 10). The mismatch between what states and survey respondents say about assessments may have to do with what each group means by alignment. For example, assessments may align with the disciplinary core ideas in the standards (leading states to say they are aligned) but not the science and engineering practices and the crosscutting concepts (leading stakeholders to say they are not).

> *Generally speaking, state assessments are not well aligned to the NGSS. They have made progress in focusing on disciplinary core ideas rather than rote knowledge and some level of application or sense-making, but there are extremely concerning gaps in grade-level appropriateness, assessing science and engineering practices and crosscutting concepts, and equity considerations.*
>
> – Assessment expert

Just as the new science standards require teachers to teach differently, they present considerable technical challenges for developers of state assessments. Multiple-choice questions are not well suited for assessing the kinds of thinking the new standards aim for — namely, thinking that requires students to simultaneously apply disciplinary science ideas, science and engineering practices, and crosscutting concepts to explain natural phenomena and design solutions to problems. New kinds of questions and scoring techniques are needed, and the high stakes associated with some state science assessments rightly create considerable pressure to ensure new assessments are technically sound. In response, NASEM commissioned a study to provide guidance for the field on developing state- and classroom-level assessments. The resulting report, *Developing Assessments for the Next Generation Science Standards* (National Research Council 2014), synthesizes the knowledge base and offers practical guidance for and examples of assessments that align with the new standards. The report does not, however, address all technical and practical challenges, and other efforts have sought to shore up the knowledge base. For example, Achieve (2018) published criteria for procuring and evaluating high-quality and aligned summative science assessments.

FIGURE 9

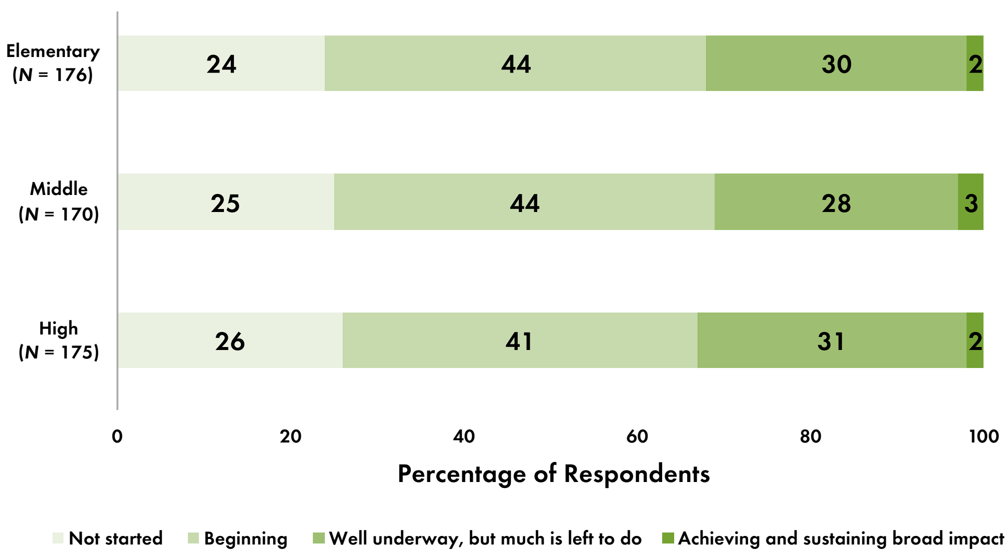
Need for Change: Assessments and Accountability



Note: Figure excludes those who responded, "I don't know."

FIGURE 10

Progress of Work toward Needed Changes: Assessments and Accountability



Note: Only those who indicated a substantial need for change saw this item.

Several states and the District of Columbia have functioned as actors, leading the field in changing their assessments to align with the new science standards. Among them are California, Illinois, Maryland, Michigan, Washington, and Wisconsin. However, as noted above, these efforts are expensive and time-consuming. With other pressures on state budgets, resources for this work are generally lacking. More than half of landscape survey respondents rated their state's funding for changing assessments as inadequate.

> *There's no funding. There's absolutely no funding for working on assessment.*
>
> – Assessment expert

Some states have joined a consortium to pool resources and learn together. The State Performance Assessment Learning Community (SPA-LC) includes Arkansas, California, Colorado, Connecticut, Delaware, Iowa, Kentucky, Massachusetts, Michigan, Missouri, Nebraska, New Mexico, Washington, and Wisconsin. It also involves several partnering organizations, including the Center for Assessment, the Council of State Science Supervisors, the Learning Policy Institute (LPI), and the Southern Regional Education Board. Led by state science leaders, facilitated by LPI, and utilizing assessment tools developed by Achieve, SPA-LC offers resources and convenings to discuss the development of student-centered performance tasks and curriculum-anchored assessment systems. This kind of infrastructure is critical for growing the knowledge base and moving the field forward. Still, only half of landscape survey respondents said formal structures exist for sharing ideas about state assessments that align with the *Framework*, and of these, almost half said the structures are inadequate.

> *[States are] struggling.... The dilemma they're facing is that if you're really asking the students to do this kind of thinking and reasoning, it takes time — the time it takes to set up the scenario or situation and then ask them to reason about it. [That] means that there's only so many items that can be given, and some of the states are using up to two or three hours for their science test.*
>
> – Assessment expert

Work is beginning at the federal level as well. The National Assessment of Educational Progress (NAEP) — also known as the Nation's Report Card — is a congressionally mandated program that assesses students across the U.S. in various subjects to provide information about student achievement. NAEP has begun revising the science framework that will shape the next national assessment.

Finally, several nongovernmental actors are contributing to the knowledge base about how to design standards-aligned assessments. Among the front-runners are the Next Generation Science Assessment project (which published a design process for NGSS-aligned assessments; Harris et al. 2016), NextGenScience (formerly Achieve, which developed assessment task screener tools), and New Meridian (which is working with states to improve science assessments with its Science Exchange model; New Meridian 2020).

Despite all these efforts, it is not clear that a field-level agenda for reforming state assessments exists. The target is clear — state assessments that align with the new science standards — but a roadmap for getting there is still emerging.

Status of Assessments and Accountability

Several states have either aligned their assessments with the new standards or are trying to do so, but in many states, perhaps most, assessments are still catching up. A knowledge base is growing, and although progress is being made on the technical challenges that standards-aligned assessments present, work remains to be done. The field benefits from the work of several actors, including states, nongovernmental organizations, and individual assessment experts, but there is clearly room for more. These actors would benefit from a field-level agenda around which to coordinate their efforts. SPA-LC is providing infrastructure for some states, but again, states and other actors need more opportunities to convene and share their work. Finally, resources for reforming state science assessments are limited, reflecting the low priority given to science education in general. ***For all these reasons, assessments and accountability are in the forming phase***.

TABLE 5

	PHASE		
Field Characteristics	**Emerging**	**Forming**	**Evolving and Sustaining**
Knowledge Base		●	
Actors		●	
Field-Level Agenda		●	
Infrastructure	●		
Resources	●		
Overall Status		○	

Preservice Teacher Preparation

Like many other professions, teaching requires a credential, and the credentialing process varies from state to state. At one time, almost all teachers earned their credential through an undergraduate teacher preparation program, culminating with exams and a probationary period before full certification. The popularity of alternative routes to certification (for example, lateral entry and residency programs) is growing, largely in response to teacher shortages. Regardless of the route, college- and university-based teacher preparation programs typically provide the coursework and practical training, preparing the vast majority of new teachers (i.e., those entering the profession in the preceding five years). In 2018, formal teacher preparation programs (i.e., those providing a credential through a bachelor's or master's degree) accounted for the majority of new science teachers — 90 percent of elementary teachers, 75 percent of middle grades teachers, and 57 percent of high school teachers (Craven and Trygstad 2020; see Table 6). Thus, these programs wield tremendous influence over the readiness of new teachers for standards-aligned science instruction.

Despite the state-level and even institution-level variation and the evolving nature of preservice teacher preparation, the influence of the NGSS is evident in national credentialing standards and exams. The Council for the Accreditation of Educator Preparation (CAEP) is the nation's largest accrediting agency for teacher preparation programs. Programs must meet CAEP's standards and pass an external review to maintain their accreditation. CAEP's (2021) standards for the initial licensure of K–6 teachers explicitly reference the NGSS. For example, one of the accreditation standards is: "Candidates demonstrate and apply understandings and integration of the three dimensions of science and engineering practices, cross-cutting concepts, and major disciplinary core ideas, within the major content areas

TABLE 6

Teachers' Paths to Certification in Science Education by Grade Range

	Percentage of Teachers		
Path to Certification	**Elementary**	**Middle**	**High**
Undergraduate program leading to a bachelor's degree and a teaching credential	75	54	33
Master's program that also led to a teaching credential	15	21	24
Postbaccalaureate credentialing program (no master's degree awarded)	8	15	26
Has not earned a teaching credential	3	10	17

Source: Craven and Trygstad (2020).

of science" (10). In 2020, two national organizations — ASTE and NSTA — jointly published standards for K–12 science teacher preparation to be used by programs and states setting licensure standards (Morrell et al. 2020) that also reflect the NGSS. That said, both the CAEP and ASTE/NSTA standards are broad, giving institutions wide latitude in how they structure their programs. Additionally, preservice teacher preparation programs typically do not prepare future teachers to identify and use high-quality science instructional materials, perhaps because until recently, few standards-aligned materials were available. Instead, programs tend to prepare preservice teachers to develop their own lessons and units. Relatedly, many of the elements in the ASTE/NSTA standards are measured by assessing an instructional unit that preservice teachers develop on their own.

The field benefits from a growing knowledge base about what preservice teacher preparation should look like if it is to support standards-aligned instruction. For example, two studies commissioned by NASEM synthesize this knowledge: *Science and Engineering for Grades 6–12: Investigation and Design at the Center* (NASEM 2019) and *Science and Engineering in Preschool through Elementary Grades: The Brilliance of Children and the Strengths of Educators* (NASEM 2021b). Published even more recently, the *Handbook of Research on Science Teacher Education* (Luft and Jones 2022) compiles research in over 30 areas related to preservice and in-service science teacher education. These include preparing specific types of teachers (e.g., early childhood, elementary, secondary), the role of field experiences in teacher preparation, and alternative pathways to teaching.

Despite this knowledge base, consensus in the field about what constitutes standards-aligned preservice teacher preparation is still emerging. Among landscape survey respondents, fewer than a third said there is broad consensus.[8] Among respondents who identified themselves as preservice teacher educators, the proportion was higher. Still, less than 50 percent said there is broad consensus. Further, more than half of all respondents said there is a substantial need to change preservice teacher preparation so that future teachers are better prepared for the shifts in instruction called for by the *Framework* (see Figure 11). More than two-thirds said this work has either not begun or is scattered, with only a small fraction of the problem being addressed (see Figure 12). Almost three-fourths of respondents said the external resources for changing preservice teacher preparation are inadequate, and more than half said that leadership for reforming preservice teacher education is inadequate. This last finding may reflect the fact that while some colleges and universities have taken the initiative to overhaul their preparation programs, national-level actors for leading widespread change are absent.

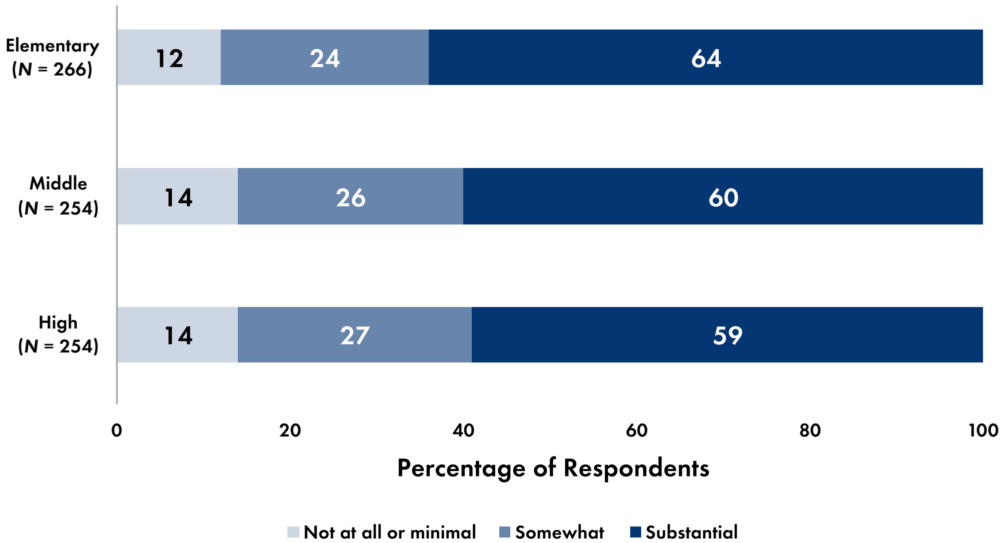
Findings from interviews conducted for this study largely support the survey findings. Interviewees pointed to the decentralized nature of teacher preparation as a potential problem. Although programs must meet accreditation standards, program faculty have broad discretion in what they do in their courses, and there are no external incentives to align their courses with the *Framework*. Consequently, there is no field-level agenda for reforming teacher preparation. Further, while some colleges and universities have taken the initiative to overhaul their teacher preparation programs, national-level actors for leading widespread change are noticeably absent.

> *I think preservice teacher education is like the worst kind of decentralized system because it's decentralized all the way down to the level of who your adjunct methods instructor is, who happens to have 30 contact hours with preservice teachers before they go out into the world.*
>
> – Curriculum development and professional learning leader

8 Gave a rating of 4 or 5 on a scale of 1 (no consensus) to 5 (broad consensus).

FIGURE 11

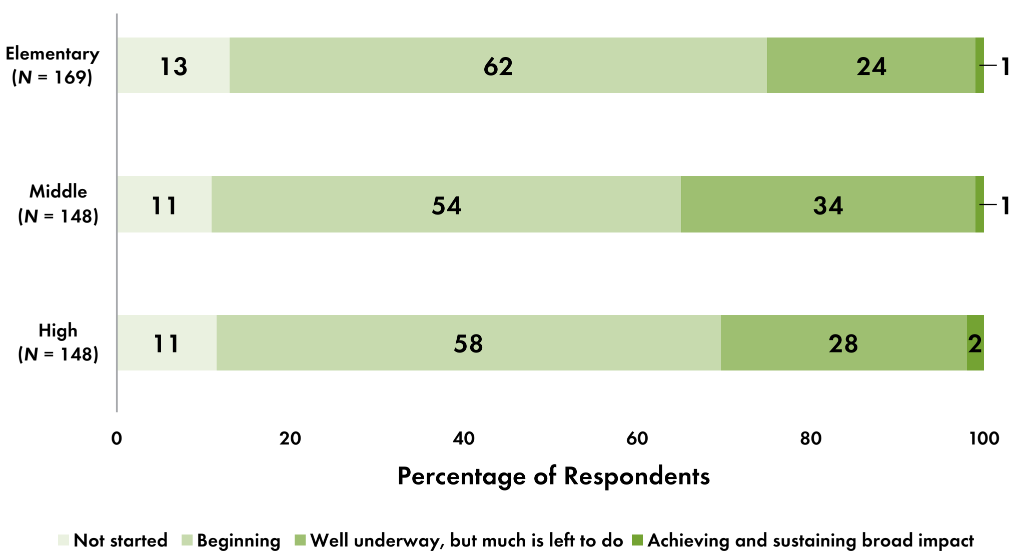
Need for Change: Preservice Teacher Preparation



Note: Figure excludes those who responded, "I don't know."

FIGURE 12

Progress of Work toward Needed Changes: Preservice Teacher Preparation



Note: Only those who indicated a substantial need for change saw this item.

ASTE is the professional organization for those who prepare preservice science teachers. It provides infrastructure for the work of reforming preservice teacher preparation through its annual conference, publications (e.g., the *Journal of Science Teacher Education*), and webinars. In 2021, ASTE published an entire issue of the *Journal of Science Teacher Education* (Campbell and Lee 2021) devoted to instructional materials designed for the NGSS and made all articles freely available. In 2022, ASTE and NSTA jointly hosted a webinar series titled *Preparing the Next Generation of Science Educators*. Because most of those who prepare preservice teachers were not classroom teachers themselves when the *Framework* and NGSS were released, they did not have opportunities to implement them. Consequently, they too would probably benefit from professional learning opportunities. Interestingly, despite ASTE's and NSTA's work, less than two-thirds of landscape survey respondents said that infrastructure exists for sharing ideas about *Framework*-aligned teacher preparation programs.

Status of Preservice Teacher Preparation

Preservice teacher preparation is even more decentralized than the K–12 system. Each program is independent, even within a state, making national reform extremely difficult. Perhaps not surprisingly, a field-level agenda for reforming teacher preparation has not taken shape. The influence of science standards is evident in accreditation standards and licensing exams, but there is no clear consensus about what standards-aligned preparation programs should look like. There is evidence of a growing knowledge base, but without actors or an agenda, that knowledge base is not likely to lead to widespread reform. ASTE provides some infrastructure through its annual conference, but otherwise, there are few convenings to discuss aligning teacher preparation with science standards. Further, resources for bringing about needed changes in teacher preparation are widely seen as inadequate. ***For these reasons, preservice teacher preparation is in the emerging phase***.

TABLE 7

	PHASE		
Field Characteristics	**Emerging**	**Forming**	**Evolving and Sustaining**
Knowledge Base		●	
Actors	●		
Field-Level Agenda	●		
Infrastructure	●		
Resources	●		
Overall Status	●		

FIELD-LEVEL ASSESSMENT

K–12 science education is complex, with many interrelated components. Standards is one of them, and arguably the most important. The fact that 48 states have adopted the NGSS or new standards influenced by the *Framework* and the NGSS over the last 10 years without any federal pressure or incentives is astounding.

In the last few years, much progress has also been made on developing standards-aligned instructional materials. For the middle grades, two comprehensive sets of fully aligned materials are available, one of which is freely available. The development of high school materials is well underway through OpenSciEd, and the development of elementary-level materials recently began. An indicator that the field is progressing would be that a substantial proportion of science classrooms are using high-quality, standards-aligned instructional materials, which is not currently the case. Another indicator would be that states, districts, and schools have several materials to choose from for each grade range. Work toward these goals will benefit from the strong knowledge base available, a field-level agenda that is garnering support, and a growing number of actors to move it forward. Some infrastructure is present, but more will be needed for field-level change. Further, the financial resources available, though considerable, come almost entirely from private foundations. More funding, including from federal sources, will be needed to realize the vision of standards-aligned instructional materials in all classrooms.

With standards largely in place and instructional materials increasingly available, the need for professional learning is immense. Yet professional learning opportunities to support standards-aligned instruction are not widespread. A strong knowledge base is available to inform the work, but currently, most infrastructure is available through national organizations such as ASTE, NSELA, and NSTA and not at the local level. Curriculum-based professional learning is a promising model, and other models exist, but a field-level agenda for making standards-aligned professional learning opportunities available to all science teachers has not emerged. And although the nation has many professional learning providers, there are not nearly enough actors to lead change at the national level. Other barriers to widespread change include insufficient time and funding provided by states and districts for professional learning, due in part to accountability pressures associated with ELA and mathematics.

Based on feedback from stakeholders and national survey data from teachers, science instruction still needs to change substantially to align with the vision of the *Framework*. The field is poised for change due to a robust knowledge base, solid infrastructure, and a field-level agenda that is taking shape. There is also a large number of actors, but they are constrained by the limited available resources and the immense number of science teachers. To move forward, the field will need more actors and substantially more resources.

State assessments, which exert considerable influence on instruction, seem to be lagging in terms of alignment. Some states have pushed ahead, but the time and money required to overhaul an assessment system, along with the technical challenges involved, are major barriers. There is a knowledge base for creating assessments that align with the new standards, but there is still much room for growth. Some initiatives, particularly SPA-LC, provide both infrastructure and actors for the work, but a field-level agenda is still taking shape, and resources for reforming state assessments are limited, according to stakeholders.

Finally, the influence of standards is evident in policies related to preservice science teacher preparation. Accreditation standards, program standards, and licensing exams reference the NGSS, but the depth of alignment is not clear, given how broad the documents are. Further, it is not clear that the experiences preservice teachers have align well with standards, and the decentralized nature of teacher preparation makes systemic change difficult. Exemplary programs exist throughout the nation, but the work lacks a field-level agenda, and a robust knowledge base is still forming. ASTE provides some infrastructure, but stakeholders see a need for much more to move the field forward. They also see the need for more actors to lead the work and more resources to fund it.

The status of K–12 science education is summarized in Table 8.

TABLE 8

Status of K–12 Science Education

PHASE		
EMERGING	FORMING	EVOLVING AND SUSTAINING
COMPONENT		
Professional learning	Instructional materials	State standards
Instruction	Assessments and accountability	
Preservice teacher preparation		

RECOMMENDATIONS TO IMPROVE THE FIELD

Only one decade in, the field can already point to a foundational success in the widespread adoption of the NGSS and standards influenced by the *Framework* and the NGSS. Other components of the system, particularly instructional materials, can also claim tangible and foundational successes. Because of these accomplishments, there is substantial momentum for continued progress with other components and, consequently, for the field as a whole. Those who study field building for population-level change stress that this work takes multiple decades to evolve and sustain. With a field as complex as K–12 science education and so tightly interwoven with society, that estimate seems realistic.

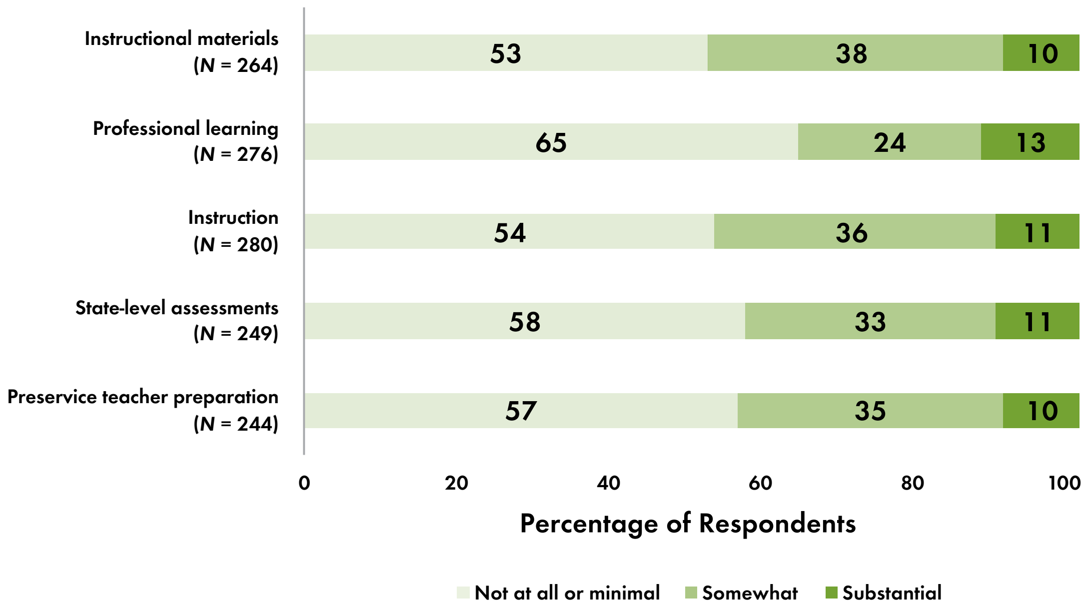
It is important to highlight two overarching obstacles that will impede progress until they are addressed. One is the status given to science by society and within the education system. *Call to Action for Science Education* emphasizes the need to "elevate the status of science education" (NASEM 2021a, 47), and three of the report's eight recommendations fall under this theme, including:

- Calling on the Office of Science and Technology Policy to use its weight to encourage government and private organizations to focus their resources on improving science opportunities for all students.
- Calling on state departments of education to include science in their accountability systems.
- Calling on national stakeholders in STEM to advocate for improving science education and addressing disparities in opportunity.

The last recommendation in the list relates to the second overarching obstacle — the chronic lack of involvement of underrepresented groups in reform efforts. The theme of educational equity runs throughout the *Framework* in its insistence on excellent science instruction for *all* students. Achieving that vision will require those who have been historically underrepresented in STEM to be deeply and consistently involved in reforming all components of the system. The landscape survey asked respondents to rate the extent to which the voices of underrepresented groups are involved in reform efforts. The results are discouraging, with more than half of respondents saying these groups are not at all involved or only minimally involved (see Figure 13). Findings from stakeholder interviews echo the survey results. Interviewees often noted that underrepresentation is a problem at all levels of the system, starting with K–12 science teachers, only one in 10 of whom are people of color (Banilower et al. 2018).

FIGURE 13

Inclusion of Historically Underrepresented Groups in Science Education Reform Initiatives



Note: Figure excludes those who responded, "I don't know."

We have to hold onto continually trying to understand the deep roots of inequitable opportunity in American schools. We're not going to make progress unless we continue to acknowledge the historical roots.... I think we also need to hold onto systemic efforts so that we have to understand that you've got to attack on all fronts. You have to have tools, you have to have curriculum that helps, you have to have assessments that help you to mount large-scale, long-term opportunities for teachers to change how they think about kids and science and teaching science in schools.

– Teacher education expert

RECOMMENDATIONS

State Standards

- The long-term viability of the Next Generation Science Standards (NGSS) and similar standards will depend on broad public support, particularly from current students and their parents and guardians, who often lead demands for change. To that end, there is a need for efforts at the state and national levels to disseminate accurate depictions of standards-aligned instruction and explain the benefits for students and society. An important societal benefit is the potential to close achievement and opportunity gaps in science by race/ethnicity.

Instructional Materials

- States, school districts, and schools should ensure teachers are equipped with high-quality instructional materials and supports to meet the needs of their students rather than asking teachers to create their own or find instructional resources on the internet. Developing coherent, yearlong, standards-aligned curricula is possible, but it requires time and expertise. Asking individual teachers to create these materials is unreasonable. Rather, teachers should be provided high-quality instructional materials and supported to adapt them to students' needs and their local context.
- States and districts should increasingly allow for the adoption of open educational resources (OER), which some states already do, in addition to instructional materials created by commercial publishers. They should also increase flexibility in how budgets for instructional materials can be spent, allowing districts and schools to purchase commercial products (e.g., print materials and consumable and nonconsumable supplies) associated with standards-aligned OER materials.

Professional Learning

- One way to improve professional learning opportunities is to center them on helping teachers use high-quality, standards-aligned instructional materials as they become available. Rather than focusing on teachers' content knowledge or teaching strategies alone, curriculum-based professional learning does both in the context of the instructional materials teachers are using. States and districts should provide curriculum-based professional learning focused on high-quality instructional materials, including OER materials.
- It is imperative that science teachers have more ongoing opportunities for professional learning. Expectations for field-level change should remain low as long as the typical teacher has less than five days of professional learning focused on science teaching over three years.
- School and district administrators who support and evaluate teachers of science should be provided with opportunities to learn about the standards and what standards-aligned instruction looks like.

Instruction

- States can make the transition to standards-aligned instruction easier for teachers by using existing infrastructure. For example, instructional coaches are relatively common in ELA and mathematics. States could direct more coaching support to science. Similarly, many states have regional centers that support schools and districts with professional learning and other services, but they tend to prioritize ELA and mathematics instruction. These centers could give more priority to science.
- As the work of improving science instruction progresses, states should put systems in place to identify and track inequities in access to standards-aligned science instruction to ensure that existing gaps begin to narrow and that new gaps do not appear. These systems should prioritize identifying and supporting schools and districts that need help, not penalizing them.

Assessments and Accountability

- Education accountability is ingrained in state and federal policy, and it prioritizes ELA and mathematics. Until science is elevated to the same level in these policies, it will continue to receive fewer resources, both financial and nonfinancial. States should include science in their accountability systems as a first step toward giving science the priority it deserves.
- Coupled with policy changes, the nation needs systems of standards-aligned science assessments that benefit students by informing changes in instruction. These should include assessments that align with the standards-aligned materials districts have adopted, enabling districts to monitor student performance locally and more frequently rather than relying on end-of-year state assessments. Assessments like these would provide better information about student learning and relieve some of the pressure teachers and students feel due to state-administered assessments.

Preservice Teacher Preparation

- Those leading the reform of preservice teacher preparation should develop a strategy that involves a large number of preservice faculty in developing model programs for preparing science teachers for standards-aligned instruction using high-quality instructional materials.
- With the growing availability of high-quality, standards-aligned instructional materials, teacher preparation programs should include a requirement for preservice teachers to demonstrate the ability to identify and use these types of materials.
- Preservice faculty should have opportunities to develop their understanding of the *Framework* and the NGSS. One strategy to accomplish this is for preservice programs to partner with schools and districts engaged in professional learning focused on standards-aligned instructional materials.

CONCLUSION

The components of K–12 science education vary widely in their progress toward field-level change. Standards are the furthest along, with 48 states having adopted the NGSS or standards influenced by the *Framework* or the NGSS. Instructional materials and assessments are in the forming phase. Both have made substantial progress, but both have much left to do. Work is progressing in both areas but more quickly for instructional materials. Professional learning, preservice teacher preparation, and instruction are all in the emerging phase. With both professional learning and instruction, a major obstacle is reaching and influencing more than a million teachers of science at the elementary level alone. The decentralized nature of preservice teacher preparation makes field-level change particularly difficult. Still, even these components that are in the emerging phase show important signs of progress, and the fact that almost all states have similar science standards should continue to push all components forward. Ultimately, though, for field-level change to happen, the nation will have to commit to (1) making science a priority on par with ELA and mathematics and (2) ensuring that underrepresented groups are integrally involved in developing and implementing a field-level agenda for change.

REFERENCES

Achieve. 2018. *Criteria for Procuring and Evaluating High-Quality and Aligned Summative Science Assessments*. Washington, D.C.: Achieve.

Achieve. 2019. *2018–19 State Science Assessment(s) in Grades 3–8*. Washington, D.C.: Achieve. achieve.org/files/Grades_3-8_Science_Assessments_Table_2018-19_final.pdf.

American Association for the Advancement of Science. 1993. *Benchmarks for Science Literacy*. New York: Oxford University Press.

Banilower, Eric R., P. Sean Smith, Kristen A. Malzahn, Courtney L. Plumley, Evelyn M. Gordon, and Meredith L. Hayes. 2018. *Report of the 2018 NSSME+*. Chapel Hill, NC: Horizon Research, Inc.

Banilower, Eric R., P. Sean Smith, Iris R. Weiss, Kristen A. Malzahn, Kiira M. Campbell, and Aaron M. Weis. 2013. *Report of the 2012 National Survey of Science and Mathematics Education*. Chapel Hill, NC: Horizon Research, Inc.

Bellwether Education Partners. 2020. *K–12 Science Curriculum Landscape Research*. Washington, D.C.: Bellwether Education Partners.

Bransford, John D., Ann L. Brown, and Rodney R. Cocking, eds. 1999. *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press.

Campbell, Todd, and Okhee Lee. 2021. "Instructional Materials Designed for *A Framework for K–12 Science Education* and the Next Generation Science Standards." Special issue, *Journal of Science Teacher Education* 32, no. 7.

Carnegie Corporation of New York. 2009. *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy*. New York: Carnegie Corporation of New York and Institute for Advanced Study Commission on Mathematics and Science Education.

Chu, Elizabeth, Grace McCarty, Molly Gurny, Naureen Madhani, Mahima Golani, and Joanna Pisacone. 2022. *Curriculum-Based Professional Learning: The State of the Field*. New York: Center for Public Research and Leadership, Columbia University.

CAEP (Council for the Accreditation of Educator Preparation). 2021. *CAEP 2018 K-6 Elementary Teacher Preparation Standards*. Washington, D.C.: Council for the Accreditation of Educator Preparation.

Craven, Laura M., and Peggy J. Trygstad. 2020. *A Comparison of Novice and Veteran Science Teachers: Data from the 2018 NSSME+*. Chapel Hill, NC: Horizon Research, Inc.

DeBoer, George E. 2014. "The History of Science Curriculum Reform in the United States." In *Handbook of Research on Science Education, Volume II*, edited by Norman G. Lederman and Sandra K. Abell, 573–592. New York: Routledge.

Doan, Sy, Maria-Paz Fernandez, David Grant, Julia H. Kaufman, Claude Messan Setodji, Joshua Snoke, Matt Strawn, and Christopher J. Young. 2021. *American Instructional Resources Surveys: 2021 Technical Documentation and Survey Results*. Santa Monica, CA: RAND Corporation. https://doi.org/10.7249/RRA134-10.

Farnham, Lija, Emma Nothmann, Zoe Tamaki, and Cora Daniels. 2020. *Field Building for Population-Level Change*. Boston: Bridgespan Group.

Harris, Christopher J., Joseph S. Krajcik, James W. Pellegrino, and Kevin W. McElhaney. 2016. *Constructing Assessment Tasks That Blend Disciplinary Core Ideas, Crosscutting Concepts, and Science Practices for Classroom Formative Applications*. Menlo Park, CA: SRI International.

Hill, Heather C., and John P. Papay. 2022. *Building Better PL: How to Strengthen Teacher Learning*. Providence, RI: Research Partnership for Professional Learning.

Luft, Julie A., and M. Gail Jones, eds. 2022. *Handbook of Research on Science Teacher Education*. New York: Routledge.

Morrell, Patricia D., Meredith A. Park Rogers, Eric J. Pyle, Gillian Roehrig, and William R. Veal. 2020. "Preparing Teachers of Science for 2020 and Beyond: Highlighting Changes to the NSTA/ASTE Standards for Science Teacher Preparation." *Journal of Science Teacher Education* 31, no. 1: 1–7. https://doi.org/10.1080/1046560X.2019.1705536.

NASEM (National Academies of Sciences, Engineering, and Medicine). n.d. "Top Downloads on NAP.edu." Accessed October 23, 2022. https://nap.nationalacademies.org/most-downloaded/.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2015. *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/21836.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2018. *How People Learn II: Learners, Contexts, and Cultures*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/24783.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2019. *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/25216.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2021a. *Call to Action for Science Education: Building Opportunity for the Future*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/26152.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2021b. *Science and Engineering in Preschool through Elementary Grades: The Brilliance of Children and the Strengths of Educators*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/26215.

National Center for Education Statistics. n.d. "NAEP Report Card: Science. Student Experiences." Retrieved January 29, 2022, from https://www.nationsreportcard.gov/science/student-experiences/.

National Center for Education Statistics. 2021. "Characteristics of Public School Teachers." https://nces.ed.gov/programs/coe/indicator/clr/.

National Research Council. 1996. *National Science Education Standards*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/4962.

National Research Council. 2005. *How Students Learn: Science in the Classroom*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/11102.

National Research Council. 2012. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/13165.

National Research Council. 2014. *Developing Assessments for the Next Generation Science Standards*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/18409.

New Meridian. 2020. *The New Meridian Framework for Quality Review of NGSS Science Assessment Items*. https://newmeridiancorp.org/wp-content/uploads/2020/12/WhitePaper-Science-Item-Review-Framework12.2020.pdf

Next Generation Science Standards. 2021. *EQuIP Rubric for Lessons and Units: Science*. https://www.nextgenscience.org/resources/equip-rubric-science.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/18290.

Plumley, Courtney L. 2019. *2018 NSSME+: Status of Elementary School Science*. Chapel Hill, NC: Horizon Research, Inc.

Short, Jim, and Stephanie Hirsh. 2020. *The Elements: Transforming Teaching through Curriculum-Based Professional Learning*. New York: Carnegie Corporation of New York.

Weiss, Iris R. 1978. *Report of the 1977 National Survey of Science, Mathematics and Social Studies Education*. Durham, NC: Research Triangle Institute.

APPENDIX: STUDY METHODS

HRI interviewed 50 stakeholders for this study, including teachers, school district and state science supervisors, college and university teacher education faculty, science education researchers, curriculum developers, professional learning providers, and funders in the U.S. Seventy individuals recognized for their involvement in science education reform and familiarity with *Framework* and the NGSS were invited to be interviewed. Some were nominated by Carnegie Corporation of New York, some by HRI, and some by interviewees themselves (i.e., HRI asked some interviewees to nominate others). Twenty of the 70 either did not respond or declined to participate. Interviews focused on the status of the field of science education in relation to Bridgespan's field characteristics.

HRI also administered a web-based survey to these same groups of stakeholders about the status of the field. Five science education professional organizations (the Association for Science Teacher Education [ASTE], the Council of State Science Supervisors [CSSS], the National Association for Research in Science Teaching [NARST], the National Science Education Leadership Association [NSELA], and the National Science Teaching Association [NSTA]) sent the survey to their members, and 356 individuals responded. We do not claim that the sample is representative. However, the respondents represent a wide range of stakeholder voices, as illustrated by their roles (see Table A-1). Note in particular the representation of teacher perspectives. Some evidence suggests that the respondents may be more knowledgeable about the field than a representative sample. For example, almost nine of 10 respondents reported having read at least parts of *A Framework for K–12 for Science Education*, and more than half reported having read the entire report.

TABLE A-1

Roles of Survey Respondents

Role	Percentage of Respondents (*N* = 356)
K–12 classroom teacher	36
College or university faculty	36
Researcher	24
K–12 professional learning provider or facilitator	19
Preservice science teacher educator	14
District or state K–12 science supervisor	13
K–12 administrator	3

Note: Percentages add to more than 100 because respondents could select more than one category.

In addition to conducting the interviews and survey, HRI reviewed national data on K–12 science education from multiple studies to help describe the status of the system's components. These studies included the National Survey of Science and Mathematics Education (NSSME; Banilower et al. 2018; Craven and Trygstad 2020; Plumley 2019; Weiss 1978), RAND's American Instructional Resources Survey (Doan et al. 2021), and the National Assessment of Educational Progress (National Center for Education Statistics n.d.). To assess the knowledge base for the field, HRI also reviewed several studies published by NASEM that synthesize knowledge about K–12 science education, including reports about instruction and professional learning (NASEM 2015, 2018, 2019, 2021a, 2021b; National Research Council 2005, 2014).

ABOUT THE AUTHORS

Horizon Research, Inc. (HRI) is a private research firm in Chapel Hill, NC, specializing in work related to science, technology, engineering, and mathematics (STEM) education. For over 35 years, HRI has provided research, evaluation, and technical assistance services to the field.

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