The Status of Elementary Science Education: Are We Ready for the Next Generation Science Standards?

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Introduction

The forthcoming Next Generation Science Standards (NGSS) aim to reshape K–12 science education, but making the vision a reality will require changes throughout the education system. What teachers ultimately do in the classroom depends on a host of factors, including state and district policies, school structures and supports, pre-service preparation, in-service learning opportunities, parent/community expectations, and availability of instructional resources, among others.

This paper highlights results about the current status of elementary science education from the 2012 National Survey of Science and Mathematics Education (NSSME), including topics such as teacher attributes (e.g., experience, college preparation), teacher beliefs about teaching and learning, instructional resources, instructional practices, professional development opportunities, and school and district policies to support science instruction. In addition, implications for implementation of the NGSS are discussed.

Study Design

The 2012 NSSME—the fifth in a series of studies funded by the National Science Foundation—is based on data from a national probability sample of approximately 10,000 science and mathematics teachers in grades K–12 in public and private schools in the 50 states and the District of Columbia. The sample was designed to allow nationally representative estimates of science and mathematics education indicators, including teacher background and instructional practices. Sample design involved clustering and stratification by elementary or secondary level, then by subject taught, and then selecting a national probability sample. Teachers in self-contained classrooms, most of them elementary teachers, were randomly assigned to either science or mathematics and received a subject-specific questionnaire. In-depth data about curriculum and instruction in a single class were obtained from each teacher (for non-self-contained teachers, a single class was randomly selected for the basis of these questions). In addition, one individual at each school was designated to respond to a survey about the school's science program. The final response rates for school program questionnaires and teacher questionnaires were 83 percent and 77 percent, respectively.[1]

Characteristics of the Elementary Science Teaching Force

This section describes the characteristics of the elementary science teaching force. In particular, general demographics (e.g., sex, race, age), content preparedness, and pedagogical beliefs are addressed and implications for implementation of the NGSS are discussed.

[1] The Report of the 2012 National Survey of Science and Mathematics (Banilower et al., 2013) provides additional information about the study design. http://www.horizon-research.com/2012nssme/research-products/reports/technical-report/

General Demographics

As can be seen in Table 1, elementary science teachers are predominately female. More than 90 percent characterize themselves as white, which is strikingly out of proportion to the student population, over one-third of which is not white. In addition, the majority of elementary science teachers are older than forty, raising concerns about having an adequate supply of science teachers in the future.

Table 1
Characteristics of the Elementary Science Teaching Force, by Grade Range

	Percent of Teachers	
	Grades K–2	**Grades 3–5**
Sex		
Male	2	11
Female	98	89
Race		
White	92	91
Black or African-American	5	6
Hispanic or Latino	8	9
Asian	1	2
American Indian/Alaskan Native	0	1
Native Hawaiian/Other Pacific Islander	0	0
Two or more races	1	1
Age		
≤ 30	19	17
31–40	27	32
41–50	24	26
51–60	20	20
61 +	10	5
Experience Teaching any Subject at the K–12 Level		
0–2 years	11	12
3–5 years	15	18
6–10 years	20	20
11–20 years	32	33
≥ 21 years	21	18
Experience Teaching Science at the K–12 Level		
0–2 years	16	17
3–5 years	15	20
6–10 years	21	21
11–20 years	29	28
≥ 21 years	19	14

Content Preparedness

The NGSS's emphasis on cross-cutting concepts, core ideas, and science practices place heavy demands on teachers' understanding of the discipline. If elementary teachers are to help students learn science concepts, they must themselves have a good understanding of the content and the discipline as a way of knowing. The 2012 NSSME used a number of proxy measures, such as teachers' major areas of study and courses completed, to ascertain the extent to which elementary teachers are likely to understand science concepts. As seen in Table 2, roughly 90 percent of elementary science teachers had college coursework in life science, and approximately

65 percent had coursework in Earth science. In contrast, fewer than half of elementary teachers had at least one college course in either chemistry or physics. The NGSS weaves engineering concepts through the standards, and fewer than 5 percent of elementary science teachers have had college coursework in engineering, suggesting that the vast majority of teachers will need substantial professional development in this area.

Table 2
Elementary Science Teachers with College Coursework in Various Science Disciplines, by Grade Range

	Percent of Teachers	
	Grades K–2	**Grades 3–5**
Life sciences /Biology	92	87
Earth/space science	66	65
Chemistry	47	47
Physics	31	34
Environmental science	33	34
Engineering	1	2
Science education	88	91
Student teaching in science	72	68

Because teachers of science in the elementary grades are typically responsible for instruction across science disciplines, the National Science Teachers Association (NSTA) has recommended that elementary science teachers demonstrate competency in life science, Earth science, and physical science. As can be seen in Table 3, approximately one third of grades K–5 teachers have had courses in all three of those areas, and another third in two of the three areas. Conversely, approximately 5 percent of elementary teachers have not had courses in any of the three areas.

Table 3
Elementary Science Teachers Meeting NSTA Course-Background Standards

	Percent of Teachers	
	Grades K–2	**Grades 3–5**
Courses in life, Earth, and physical science[†]	36	36
Courses in only two of the three areas	41	36
Courses in only one of the three areas	18	23
No courses in any of the three areas	5	6

[†] Physical science is defined as a course in either chemistry or physics.

Elementary science teachers' minimal background in science is reflected in their perceptions of their own content preparedness. Because elementary teachers are typically responsible for teaching not only science, but also mathematics, reading/language arts, and other academic subjects to one group of students, the survey asked them to rate their content preparedness in each of those subjects (see Table 4). It is clear that elementary school teachers do not feel

equally well prepared to teach all academic subjects, with perceptions of preparedness to teach science paling in comparison to reading/language arts and mathematics.

Table 4
Elementary Science Teachers' Perceptions of their Preparedness to Teach Each Subject, by Grade Range

	Percent of Teachers†			
	Not Adequately Prepared	**Somewhat Prepared**	**Fairly Well Prepared**	**Very Well Prepared**
Grades K–2				
Reading/Language Arts	0	1	13	86
Mathematics	1	4	17	78
Social Studies	1	10	40	48
Science	2	12	43	44
Grades 3–5				
Reading/Language Arts	0	3	23	74
Mathematics	1	2	21	76
Social Studies	2	13	41	44
Science	3	19	44	33

† Includes only teachers assigned to teach all four subjects to a single class of students.

Elementary teachers were also asked about their content preparedness to teach various disciplines within science, as well as engineering. As can be seen in Table 5, about one-third of teachers said they are very well prepared to teach both life science and Earth science. Only 16 percent indicate that they are very well prepared to teach physical science. Engineering stands out as the area where elementary teachers feel least prepared, as roughly 7 in 10 teachers rated themselves the lowest point on the scale in this area.

Table 5
Elementary Science Teachers' Perceptions of their Preparedness to Teach Various Science Disciplines, by Grade Range

	Percent of Teachers†			
	Not Adequately Prepared	**Somewhat Prepared**	**Fairly Well Prepared**	**Very Well Prepared**
Grades K–2				
Life Science	4	20	45	32
Earth Science	4	26	42	28
Physical Science	9	31	44	16
Engineering	77	14	6	3
Grades 3–5				
Life Science	4	22	48	26
Earth Science	4	25	48	23
Physical Science	7	35	39	19
Engineering	69	22	5	4

† Includes only teachers assigned to teach mathematics, reading/language arts, science, and socials studies to a single class of students.

Taken together, these data suggest that elementary science teachers will need support to teach both the disciplinary core ideas and crosscutting concepts in the NGSS. This finding seems especially true for Earth/space science, physical science, and engineering, as relatively few teachers have taken college coursework in these areas and do not feel adequately prepared to teach them.

Pedagogical Beliefs

In the survey, teachers were asked about their beliefs regarding effective teaching and learning in science. Table 6 shows that more than 90 percent of elementary teachers agree that: (1) most class periods should provide opportunities for students to share their thinking and reasoning, (2) most class periods should conclude with a summary of the key ideas addressed, (3) students should be provided with the purpose for a lesson as it begins, and (4) most class periods should include some review of previously covered ideas and skills. Each of these beliefs aligns well with what is known about effective science teaching (e.g., Bransford, Brown, & Cocking, 1999; Banilower, Cohen, Pasley, & Weiss, 2010). In addition, 65 percent of grades K–2 teachers and 79 percent of grades 3–5 teachers agreed that it is better to focus on ideas in depth even if it means covering fewer topics, which is one of the central tenets of calls for reform in science education.

Inconsistent with what the field knows about effective teaching, 40 percent of elementary teachers agree that teachers should explain an idea to students before having them consider evidence for that idea, and more than half indicate that hands-on/laboratory activities should be used primarily to reinforce ideas that the students have already learned. And despite recommendations that students develop understanding of concepts first and learn the scientific language later, over 80 percent of elementary science teachers agree that students should be given definitions for new vocabulary at the beginning of instruction on an idea. Given that the elements of effective science instruction are reflected in the scientific practices of the NGSS, these inconsistencies in teacher pedagogical beliefs represent a potential barrier to putting the NGSS into practice.

Table 6
Elementary Science Teachers Agreeing† with Various Statements about Teaching and Learning, by Grade Range

	Percent of Teachers	
	Grades K–2	**Grades 3–5**
Most class periods should provide opportunities for students to share their thinking and reasoning.	97	99
Most class periods should conclude with a summary of the key ideas addressed.	96	96
Students should be provided with the purpose for a lesson as it begins.	93	92
Most class periods should include some review of previously covered ideas and skills.	92	91
Inadequacies in students' science background can be overcome by effective teaching.	88	90
At the beginning of instruction on a science idea, students should be provided with definitions for new scientific vocabulary that will be used.	86	84
It is better for science instruction to focus on ideas in depth, even if that means covering fewer topics.	65	79
Hands-on/laboratory activities should be used primarily to reinforce a science idea that the students have already learned.	53	54
Teachers should explain an idea to students before having them consider evidence that relates to the idea.	49	41
Students should be assigned homework most days.	37	38
Students learn science best in classes with students of similar abilities.	27	37

† Includes teachers indicating "strongly agree" or "agree" on a 5-point scale ranging from 1 "strongly disagree" to 5 "strongly agree."

Elementary Science Instruction

This section focuses on teachers' descriptions of what transpires during elementary school science instruction in the United States, including frequency of instruction, instructional materials used, instructional objectives, and instructional activities. Each teacher responding to the survey who taught science to more than one class per day was asked to provide detailed information about a randomly selected class.

Frequency and Duration

Teachers were asked how often they teach science. As shown in Table 7, only 18 percent of grades K–2 classes and 29 percent of grades 3–5 classes receive science instruction all or most days every week of the school year. A substantial percentage of elementary classes receive science instruction only a few days a week or during some weeks of the year.

Table 7
Frequency with which Self-Contained
Elementary Science Teachers Teach Science, by Grade Range

	Percent of Classes	
	Grades K–2	**Grades 3–5**
All/Most days, every week	19	30
Three or fewer days, every week	40	33
Some weeks, but not every week	41	36

The survey also asked the approximate number of minutes typically spent on teaching mathematics, reading/language arts, science, and social studies in self-contained classes (see Table 8). Classes in grades K–2 spend an average of 18 minutes per day on science, compared to 90 minutes on reading/language arts and 52 minutes on mathematics. A similar trend is seen in grades 3–5 as science is taught an average of 23 minutes per day compared to 85 minutes for reading/language arts and 61 minutes for mathematics.

Table 8
Average Number of Minutes per Day Spent
Teaching Each Subject in Self-Contained Classes[†]

	Number of Minutes	
	Grades K–2	**Grades 3–5**
Reading/Language Arts	90	85
Mathematics	52	61
Science	18	23
Social Studies	16	19

[†] Only teachers who indicated they teach reading/language arts, mathematics, science, and social studies to one class of students were included in these analyses.

The frequency and duration of elementary science instruction as compared to other academic subjects is striking. Going forward, more science instructional time is critical in order to prepare students to meet NGSS performance expectations. Without more instructional time devoted to science, students will not have opportunity to engage with many of the concepts, ideas, and practices described by the NGSS.

Instructional Materials

The 2012 National Survey collected data on the use of commercially published textbooks or programs in science classes. As can be seen in Table 9, 60 percent of grades K–2 classes and 77 percent of grades 3–5 classes use commercially published textbooks or programs.

Table 9
Classes Using Commercially Published Science Textbooks/Programs

	Percent of Classes
Grades K–2	60
Grades 3–5	77

Teachers utilizing a published textbook/program were asked to record the title, author, year, and ISBN of the material used most often in the class. Using this information, the publisher of the material was identified. Table 10 shows the market share held by each of the major science and mathematics textbook publishers. It is interesting to note that four publishers—Houghton Mifflin Harcourt, McGraw-Hill, Pearson, and Delta Education—account for instructional materials used in nearly 90 percent of elementary science classes.

Table 10
Market Share of Commercial Science Textbook Publishers in Elementary Science Classes

	Percent of Classes
Houghton Mifflin Harcourt	47
McGraw-Hill	16
Pearson	15
Delta Education	11
National Geographic Society	4
Carolina Biological Supply Company	2

Teachers were also asked about the percentage of instructional time spent using these instructional materials. Table 11 shows that over half of elementary science classes use instructional materials at least 50 percent of the time.

Table 11
Percent of Instructional Time Spent Using Instructional Materials During the Course,† by Grade Range

	Percent of Classes	
	Grades K–2	Grades 3–5
Less than 25 percent	25	9
25–49 percent	25	28
50–74 percent	17	25
75 percent or more	32	37

† Only classes using published textbooks/programs were included in these analyses.

However, much science instruction in the elementary grades appears to be pulled together from multiple sources (see Table 12). Notable is the relatively heavy use of non-commercially published materials, particularly in grades K–2.

Table 12
Elementary Science Classes Using
Textbooks and/or Programs, by Grade Range

	Percent of Classes	
	Grades K–2	**Grades 3–5**
Mainly commercially published textbook(s)		
One textbook	21	30
Multiple textbooks	3	5
Mainly commercially published modules		
Modules from a single publisher	12	13
Modules from multiple publishers	3	5
Other		
A roughly equal mix of commercially published textbooks and commercially published modules most of the time	21	23
Non-commercially published materials most of the time	40	23

Further, it is clear that when teachers do use textbooks, they deviate from them when designing instruction. About three-fourths of teachers reported using a textbook substantially to guide the overall structure and content emphasis, and 65 percent reported using the textbook for more detailed organization (see Table 13). Yet, in more than half of science classes, teachers reported incorporating activities from other sources substantially, and in approximately 40 percent of classes, teachers reported skipping portions of the textbook that were deemed unimportant.

Table 13
Ways Elementary Science Teachers Substantially[†]
Used their Textbook in Most Recent Unit, by Grade Range

	Percent of Classes[‡]	
	Grades K–2	**Grades 3–5**
You used the textbook/module to guide the overall structure and content emphasis of the unit.	73	79
You followed the textbook/module to guide the detailed structure and content emphasis of the unit to supplement what the textbook/module was lacking.	65	65
You incorporated activities (e.g., problems, investigations, readings) from other sources to supplement what the textbook/module was lacking.	65	64
You picked what is important from the textbook/module and skipped the rest.	41	43

[†] Includes those responding 4 or 5 on a 5-point scale ranging from 1 "not at all" to 5 "to a great extent."
[‡] Only classes using published textbooks/programs in the most recent unit were included in these analyses.

As seen in Table 14, the most often selected reason for skipping an activity in a textbook is having another activity that works better than the one skipped. In addition, in 58 percent of grades K–2 classes and 71 percent of grades 3–5 classes, teachers reported skipping activities that were not included in their pacing guide and/or state standards. Similarly, textbooks were supplemented in just over half of elementary science classes because the pacing guide indicated that supplemental activities should be used (see Table 15).

Table 14
Reasons Why Parts of the Textbook Are Skipped, by Grade Range

	Percent of Classes[†]	
	Grades K–2	**Grades 3–5**
You have different activities for those science ideas that work better than the ones you skipped.	87	81
The science ideas addressed in the activities you skipped are not included in your pacing guide and/or current state standards.	58	71
You did not have the materials needed to implement the activities you skipped.	55	67
Your students already knew the science ideas or were able to learn them without the activities you skipped.	60	59
The activities you skipped were too difficult for your students.	52	49

[†] Only classes using published textbooks/programs in the most recent unit and whose teachers reported skipping some activities were included in these analyses.

Table 15
Reasons Why the Textbook is Supplemented, by Grade Range

	Percent of Classes[†]	
	Grades K–2	**Grades 3–5**
Supplemental activities were needed so students at different levels of achievement could increase their understanding of the ideas targeted in each activity.	92	94
Supplemental activities were needed to provide students with additional practice.	80	91
Supplemental activities were needed to prepare students for standardized tests.	31	62
Your pacing guide indicated that you should use supplemental activities.	59	58

[†] Only classes using published textbooks/programs in the most recent unit and whose teachers reported skipping some activities were included in these analyses.

With the release of the NGSS, it will be important for districts, schools, and teachers to consider the alignment of their instructional materials to these standards. Although this undertaking is potentially overwhelming, particularly when non-commercially published materials are being used, the fact that the majority of classes use materials from only four publishers may be a potential leverage point for implementing the NGSS. Working with these publishers to align their material with the NGSS affords a greater probability that the standards will be widely implemented and taught as intended.

In addition, both the willingness and means to make curricular modifications will be important when current materials are not aligned with the NGSS. Given that classroom instruction is heavily influenced by pacing guides, adoption of the NGSS will likely require a substantial overhaul of these documents.

Instructional Objectives

The survey provided a list of possible objectives of science instruction and asked teachers how much emphasis each would receive over an entire year. Table 16 shows that teachers report heavy emphasis in science classes on instructional objectives that are aligned with both reform-oriented instruction and the NGSS, such as understanding science concepts and increasing students' interest in science.

Table 16
Elementary Science Classes with Heavy Emphasis on Various Instructional Objectives, by Grade Range

	Percent of Classes	
	Grades K–2	Grades 3–5
Understanding science concepts	47	69
Increasing students' interest in science	55	56
Learning science process skills (e.g., observing, measuring)	45	49
Learning about real-life applications of science	47	45
Preparing for further study in science	34	35
Learning test taking skills/strategies	13	30
Memorizing science vocabulary and/or facts	6	14

The objectives related to reform-oriented instruction (understanding science concepts, increasing students' interest in science, learning science process skills, preparing for further study in science, and learning about real-life applications of science) were combined into a composite variable through factor analysis of all survey items.[2] Overall, scores on this composite are fairly high across for both grades K–2 and grades 3–5 (see Table 17), suggesting that teachers generally see themselves as emphasizing reform-oriented instructional objectives.

Table 17
Elementary Science Class Mean Scores on the Reform-Oriented Instructional Objectives Composite, by Grade Range

	Mean Score
Grades K–2	78
Grades 3–5	80

Instructional Activities

Teachers were also given a list of activities and asked how often they did each in the randomly selected class; response options were: never, rarely (e.g., a few times a year), sometimes (e.g., once or twice a month), often (e.g., once or twice a week), and all or almost all science lessons. As can be seen in Table 18, three instructional activities occur at least once a week in most elementary science classes: explaining science ideas to the whole class, engaging the whole class in discussions, and having students work in small groups. Note that a number of activities closely aligned with the NGSS occur weekly in less than half of science classes, including:

- Having students write reflections;

[2] All composite variables created for the 2012 NSSME have a minimum possible score of 0 and a maximum of 100. For a full description of how composite variables were created, please see the Report of the 2000 National Survey of Science and Mathematics Education (http://www.horizon-research.com/2012nssme/research-products/reports/technical-report/)

- Having students represent and/or analyze data using tables, charts, or graphs; and
- Engaging the class in project-based learning (PBL) activities.

Table 18
Elementary Science Classes in Which Teachers Report Using Various Activities at Least Once a Week, by Grade Range

	Percent of Classes	
	Grades K–2	**Grades 3–5**
Engage the whole class in discussions	90	91
Explain science ideas to the whole class	87	89
Have students work in small groups	65	79
Require students to supply evidence in support of their claims	46	62
Do hands-on/laboratory activities	54	55
Have students read from a science textbook, module, or other science-related material in class, either aloud or to themselves	39	55
Focus on literacy skills (e.g., informational reading or writing strategies)	45	51
Have students write their reflections (e.g., in their journals) in class or for homework	38	48
Have students represent and/or analyze data using tables, charts, or graphs	42	46
Give tests and/or quizzes that are predominantly short-answer (e.g., multiple choice, true /false, fill in the blank)	19	41
Give tests and/or quizzes that include constructed-response/open-ended items	12	29
Engage the class in project-based learning (PBL) activities	31	29
Have students practice for standardized tests	10	28
Have students make formal presentations to the rest of the class (e.g., on individual or group projects)	10	14
Have students attend presentations by guest speakers focused on science and/or engineering in the workplace	2	4

In addition to asking about class activities in the course as a whole, the 2012 NSSME asked teachers about activities that took place during their most recent science lesson. Table 19 shows that over half of elementary science lessons included the teacher explaining a science idea to the whole class and whole class discussion. In addition, about half of elementary lessons included students doing hands-on/laboratory activities.

Table 19
Elementary Science Classes Participating in Various Activities in Most Recent Lesson, by Grade Range

	Percent of Classes	
	Grades K–2	Grades 3–5
Whole class discussion	93	89
Teacher explaining a science idea to the whole class	92	87
Students reading about science	46	59
Students doing hands-on/laboratory activities	57	48
Students completing textbook/worksheet problems	37	47
Teacher conducting a demonstration while students watched	44	36
Students using instructional technology	19	24
Test or quiz	8	16
Practicing for standardized tests	2	7

The prevalence of teacher explanation and the relative infrequency of other activities (e.g., doing hands-on/laboratory activities) suggests that students may have limited opportunities to engage in the scientific practices described in the NGSS.

Professional Development of Elementary Science Teachers

Science and mathematics teachers, like all professionals, need opportunities to keep up with advances in their field, including both disciplinary content and how to help their students learn important science/mathematics content. In this paper, we have argued that professional development experiences will be particularly important as the NGSS make their way into schools. However, staying up-to-date is particularly challenging for teachers at the elementary level, as they typically teach multiple subjects. This section describes elementary science teachers' participation in science-focused professional development, as well as the characteristics of those professional development offerings.

Participation in Professional Development

Over half of elementary teachers indicated they had participated in science-focused professional development in the last three years. In contrast, roughly 15 percent of teachers reported never participating in science-focused professional development (see Table 20).

Table 20
Elementary Science Teachers' Most Recent Participation in Science-Focused† Professional Development, by Grade Range

	Percent of Teachers	
	Grades K–2	Grades 3–5
In the last 3 years	56	62
4–6 years ago	18	15
7–10 years ago	6	5
More than 10 years ago	5	4
Never	16	14

† Includes professional development focused on science or science teaching.

Although some involvement in professional development is better than none, brief exposure of a few hours over several years is not likely to be sufficient to enhance teachers' knowledge and skills in meaningful ways, especially considering the substantial changes anticipated with the NGSS. Accordingly, teachers were asked about the total amount of time they had spent on professional development related to science teaching. As can be seen in Table 21, over 60 percent of elementary teachers spent less than six hours in science-related professional development in the last three years.

Table 21
Time Spent on Professional Development in the Last Three Years, by Grade Range

	Percent of Teachers	
	Grades K–2	Grades 3–5
Less than 6 hours	68	62
6–15 hours	22	23
16–35 hours	7	9
More than 35 hours	3	6

These data suggest a need for increased science-focused professional development with the release of the NGSS. The fact that about two-thirds of elementary teachers experienced less than six hours of professional development over three years points to a significant barrier in the NGSS implementation process. A fundamental change in the professional development system is needed to provide teachers the support they will need.

Professional Development Activities

Teachers who indicated they had recently participated in professional development were asked about the nature of those activities. The vast majority of elementary teachers attended a workshop on science or science teaching (see Table 22). In addition, over half of teachers reported participating in professional learning community or other types of teacher study groups.

Table 22
Elementary Science Teachers Participating in Various Professional Development Activities in Past Three Years, by Grade Range

	Percent of Teachers	
	Grades K–2	Grades 3–5
Attended a workshop on science or science teaching	85	84
Participated in a professional learning community/lesson study/teacher study group focused on science or science teaching	54	55
Received feedback about your science teaching from a mentor/coach formally assigned by the school/district/diocese[†]	22	25
Attended a national, state, or regional science teacher association meeting	4	11

Table 23 shows that many science teachers (56 percent in grades 3–5 and 41 percent in grades K–2) have had opportunities to engage in science investigations. In addition, about one-third of teachers have had opportunities to work with other science teachers in their schools, work with other science teachers in the same grade and/or subject, try out what they learned and then talk about it, and examine classroom artifacts.

Table 23
Elementary Science Teachers Whose Professional Development in the Last Three Years Had Each of a Number of Characteristics to a Substantial Extent,[†] by Grade Range

	Percent of Teachers	
	Grades K–2	Grades 3–5
Had opportunities to engage in science investigations	41	56
Worked closely with other science teachers who taught the same grade and/or subject whether or not they were from your school	33	41
Worked closely with other science teachers from your school	29	40
Had opportunities to try out what you learned in your classroom and then talk about it as part of the professional development	34	34
Had opportunities to examine classroom artifacts (e.g., student work samples)	32	31
The professional development was a waste of time	7	9

[†] Includes teachers indicating 4 or 5 on a 5-point scale ranging from 1 "Not at all" to 5 "To a great extent."

Another series of items asked about the focus of opportunities teachers had to learn about content and the teaching of that content in the last three years, whether through professional development or college coursework. Almost half of elementary teachers said that their recent professional development/coursework heavily emphasized assessing student understanding at the end of instruction on a topic, planning instruction to enable students at different levels of achievement to enhance their understanding of the targeted ideas, and monitoring student understanding during instruction (see Table 24). However, fewer teachers (39 percent of grades K–2 teachers and 36 percent of grades 3–5 teachers) reported opportunities to deepen their science content knowledge.

Table 24
Science Teachers Reporting That Their Professional Development/Coursework in the Last Three Years Gave Heavy Emphasis† to Various Areas, by Grade Range

	Percent of Teachers	
	Grades K–2	**Grades 3–5**
Assessing student understanding at the conclusion of instruction on a topic	45	49
Planning instruction so students at different levels of achievement can increase their understanding of the ideas targeted in each activity	48	46
Monitoring student understanding during science instruction	45	44
Implementing the science textbook/module to be used in their classroom	40	39
Finding out what students think or already know about the key science ideas prior to instruction on those ideas	46	37
Deepening their science content knowledge	39	36
Providing enrichment experiences for gifted students	29	35
Learning about difficulties that students may have with particular science ideas and procedures	29	32
Providing alternative science learning experiences for students with special needs	21	22
Teaching science to English-language learners	20	21

† Includes teachers responding 4 or 5 on a 5-point scale ranging from 1 "Not at all" to 5 "To a great extent."

That current professional development has a number of positive characteristics bodes well for future efforts to prepare teachers for the NGSS. For example, engaging in science investigations is a possible way for teachers to be prepared to integrate the scientific practices into their classroom instruction. Still, the data indicate that a much greater effort will be needed to provide teachers with in-depth, sustained opportunities to deepen their knowledge of the disciplinary core ideas, crosscutting concepts, and practices inherent in the NGSS.

Characteristics of School-level Professional Development

The 2012 NSSME also included School Program Questionnaires for science and mathematics, each completed by an individual knowledgeable about school programs, policies, and practices in the designated subject. Program representatives were asked whether professional development workshops in the designated discipline were offered by their school and/or district (if relevant), possibly in conjunction with other school systems, colleges or universities, museums, professional associations, and/or commercial vendors. Science-focused professional development workshops were offered in 48 percent of elementary schools in the last three years. Over half of these workshops had a substantial focus on state science standards, science content, and how to use particular science instructional materials (see Table 25).

Table 25
Locally Offered Professional Development Workshops in the Last Three Years with a Substantial Focus† in Each of a Number of Areas

	Percent of Elementary Schools
State science standards	61
How to use particular science instructional materials	57
How to use investigation-oriented science teaching strategies	55
Science content	54
How to use technology in science instruction	37
How students think about various science ideas	33
How to monitor student understanding during science instruction	31
How to adapt science instruction to address student misconceptions	31
How to teach science to students who are English language learners	18
How to provide alternative science learning experiences for students with special needs	10

† Includes schools where respondent indicated 4 or 5 on a 5-point scale ranging from 1 "Not at all" to 5 "To a great extent."

Science-focused teacher study groups were offered in 32 percent of elementary schools in the last three years. Of these, nearly three-fourths met once a month or more often, and 84 percent lasted the entire school year (see Table 26). Program representatives reported that study groups most often comprised teachers in the school, but also commonly included other schools in the district (see Table 27). Over half of study groups included teachers from multiple grade levels and administrators.

Table 26
Frequency and Duration of Teacher Study Groups with a Specified Schedule

	Percent of Elementary Schools†
Frequency	
Less than once a month	35
Once a month	38
Twice a month	7
More than twice a month	20
Duration	
The entire school year	84
One semester	11
Less than one semester	4

† Includes only those schools that offered teacher study groups in the last three years with specified schedules.

Table 27
Composition of Teacher Study Groups

	Percent of Elementary Schools†
Include teachers from multiple grade levels	62
Limited to teachers from this school	58
Include school and/or district/diocese administrators	52
Include teachers from other schools in the district/diocese‡	45
Include higher education faculty or other "consultants"	13
Include teachers from other schools outside of their jurisdiction	12
Include parents/guardians or other community members	0

† Includes only those schools that offered teacher study groups in the last three years.
‡ Item presented only to public and Catholic schools.

Taken together, these data suggest that there is an infrastructure for school-level professional development in many schools that could be leveraged to support teachers as they adopt the NGSS. Schools that already have teacher study groups (or PLCs) in place will have an advantage, as they already have time and structured opportunity for ongoing discussions about science instruction. However, fewer than half of elementary teachers had opportunities to participate in science focused workshops or professional learning groups in the last three years. Prospects for successful implementation of the NGSS will not be promising without a substantial increase in science-focused professional development opportunities for teachers.

Other Factors Affecting Elementary Science Instruction

The 2012 NSSME also collected information on the context of classroom practice. Program representatives and teachers were asked about various factors that affect science instruction in elementary schools and classrooms, including instructional arrangements, availability of facilities and equipment, and opportunities for professional development.

Instructional Arrangements

The designated school program representatives were asked about several instructional arrangements for students in self-contained classrooms. As seen in Table 28, the use of science specialists, either in place of or in addition to the regular classroom teacher, is uncommon. Pull-out instruction, whether for remediation or enrichment, is also quite rare. Given that the bulk of science instruction rests squarely with classroom teachers, it is essential that elementary teachers are trained and supported in their use of the NGSS.

Table 28
Use of Instructional Arrangements in Elementary Schools

	Percent of Elementary Schools
Students in self-contained classes pulled out from science instruction for additional instruction in other content areas	22
Students in self-contained classes receive science instruction from a science specialist *in addition* to their regular teacher	16
Students in self-contained classes receive science instruction from a science specialist *instead of* their regular teacher	10
Students in self-contained classes pulled out for enrichment in science.	10
Students in self-contained classes pulled out for remedial instruction in science	7

Factors that Promote and Inhibit Science Instruction

Program representatives were asked to indicate the influence of a number of factors on science instruction in their school. As shown in Table 29, four factors are perceived as promoting effective elementary science instruction in just over half of schools: (1) importance that the school places on science, (2) district science professional development policies and practices, (3) public attitudes toward science instruction, and (4) how instructional resources are managed. Conversely, time for teacher professional development in science and conflict between efforts to improve science instruction and other district initiatives are both seen as inhibiting effective science instruction in almost one-third of schools. The negative influence of time for professional development is consistent with other findings, most notably that the vast majority of elementary teachers have few opportunities for continued learning about science or science teaching.

Table 29
Effect† of Various Factors on Science Instruction

	Percent of Elementary Schools		
	Inhibits	Neutral	Promotes
Importance that the school places on science	20	21	59
District/Diocese science professional development policies and practices	13	34	53
Public attitudes toward science instruction	10	38	52
How science instructional resources are managed (e.g., distributing and refurbishing materials)	23	25	52
Time provided for teacher professional development in science	29	29	42
Conflict between efforts to improve science instruction and other school/district/diocese initiatives	33	41	25

† Respondents rated the effect of each factor on a 5-point scale ranging from 1 "inhibits effective instruction" to 5 "promotes effective instruction." The "Inhibits" column includes those responding 1 or 2. The "Promotes" column includes those responding 4 or 5.

Program representatives were also asked to rate each of several factors as either not a significant problem, somewhat of a problem, or a serious problem for science instruction (see Table 30). Resource-related issues were most often cited as a serious problem; including inadequate funds for purchasing science equipment and supplies (30 percent), lack of science facilities (27

percent), and inadequate materials for individualizing science instruction (21 percent). Insufficient time to teach science (27 percent) and inadequate science-related professional development opportunities (23 percent) are also as serious problems in many elementary schools.

Table 30
Science Program Representatives Viewing Each of a Number of Factors as a Serious Problem for Science Instruction in Their School

	Percent of Elementary Schools
Inadequate funds for purchasing science equipment and supplies	30
Lack of science facilities (e.g., lab tables, electric outlets, faucets and sinks in classrooms)	27
Insufficient time to teach science	27
Inadequate science-related professional development opportunities	23
Inadequate materials for individualizing science instruction	21
Lack of opportunities for science teachers to share ideas	20
Low student reading abilities	16
Inadequate supply of science textbooks/modules	14
Large class sizes	13
Inadequate teacher preparation to teach science	11
Lack of parental support for science education	10
Inappropriate student behavior	9
High student absenteeism	8
Interruptions for announcements, assemblies, and other school activities	8
Low student interest in science	5
Lack of teacher interest in science	4
Community resistance to the teaching of "controversial" issues in science (e.g., evolution, climate change)	3

In addition, teachers were asked about factors that affect their science instruction (see Table 31). In approximately 70 percent of science classes, teachers rate principal support as promoting effective science instruction. Conversely, factors seen as inhibiting science instruction in more than 20 percent of K-5 classes are: time for planning, time available for professional development, and textbook/module selection policies. Teachers also see students' reading abilities and state and district testing/accountability policies as inhibiting effective science instruction in a substantial percentage of grades 3–5 classes.

Table 31
Effect† of Various Factors on
Instruction in Randomly Selected Science Class

	Percent of Classes		
	Inhibits	**Neutral**	**Promotes**
Grades K–2			
Students' motivation, interest, and effort in science	6	11	83
Principal support	8	24	68
Current state standards	6	27	67
District/Diocese curriculum frameworks	10	26	64
Students' reading abilities	18	24	57
Time for you to plan, individually and with colleagues	27	16	57
District/Diocese/School pacing guides	13	34	53
Parent expectations and involvement	15	35	50
Time available for your professional development	27	23	50
Teacher evaluation policies	12	38	49
Community views on science instruction	11	44	46
Textbook/module selection policies	24	36	40
District/Diocese testing/accountability policies	16	50	38
State testing/accountability policies	17	49	33
Grades 3–5			
Students' motivation, interest, and effort in science	7	17	76
Principal support	6	23	71
Current state standards	7	27	66
District/Diocese curriculum frameworks	8	28	64
Students' reading abilities	26	17	57
Time for you to plan, individually and with colleagues	29	19	52
District/Diocese/School pacing guides	13	29	58
Parent expectations and involvement	17	39	44
Time available for your professional development	25	26	48
Teacher evaluation policies	9	45	47
Community views on science instruction	14	47	39
Textbook/module selection policies	22	33	50
District/Diocese testing/accountability policies	22	31	46
State testing/accountability policies	21	33	46

† Respondents rated the effect of each factor on a 5-point scale ranging from 1 "inhibits effective instruction" to 5 "promotes effective instruction." The "Inhibits" column includes those responding 1 or 2. The "Promotes" column includes those responding 4 or 5.

The lack of resources for science instruction represents a significant impediment to the NGSS. In addition to the new standards, many elementary teachers will have to contend with not having the necessary equipment, facilities, materials, or time for science teaching.

Discussion

Data from the 2012 National Survey of Science and Mathematics Education suggest that schools and districts are woefully unprepared for the NGSS in several areas. First and foremost, the frequency and duration of elementary science instruction is noticeably inadequate, averaging

only about 20 minutes a day. Without more instructional time devoted to science, students will not have opportunity to engage with the concepts, ideas, and practices described by the NGSS.

Second, schools and districts must equip teachers with the supplies and materials they need for science instruction. Teachers cannot be expected to successfully implement the NGSS without the resources to carry out instructional activities that provide students with opportunities to use the scientific practices in the standards.

Finally, serious consideration should be given to how the professional development system needs to be adjusted, in terms of the amount, structure, and content of science-focused professional development, to support implementation of the NGSS. A substantial proportion of elementary teachers see themselves as inadequately prepared to teach chemistry, physics, and especially engineering topics. Furthermore, program representatives and teachers both indicate that current science-related professional development opportunities are lacking. Considering that the use of science specialists and pull-out instruction for both remediation and enrichment are rare, professional development will be critical for preparing classroom teachers to successfully implement the NGSS.

This paper also points to potential leverage points. For instance, although teachers hold some views contrary to learning theory (e.g., providing definitions prior to experience, using hands-on activities primarily to reinforce ideas already learned), they also express views about science instruction that closely align with what is known about how students learn (e.g., most class periods should provide opportunities for students to share their thinking and reasoning, most class periods should conclude with a summary of the key ideas addressed). In addition, teachers generally see themselves as emphasizing reform-oriented instructional objectives, and they report incorporating multiple modes of engagement, frequently utilizing class discussions and hands-on/laboratory activities. The challenge for the field will be making the most of these areas of opportunity while simultaneously supporting teachers to deepen their content knowledge and align their practice more closely with the vision of science instruction expressed in the NGSS.

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