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What Does a National Survey Tell Us about Progress toward the Vision of the NGSS?

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The National Survey of Science and Mathematics Education (NSSME) has provided periodic snapshots of K–12 science instruction in the United States for over 40 years. Study topics include teacher background and beliefs, professional learning opportunities, course offerings, instructional objectives and activities, resources for instruction, and policies affecting instruction. First conducted in 1977 as part of a larger study commissioned by the National Science Foundation, successive iterations occurred in 1985, 1993, 2000, 2012, and 2018. The two most recent studies coincidentally share important milestones with the Next Generation Science Standards (NGSS; the NGSS Lead States, 2013) (see Figure 1). In July 2011, the National Research Council published the Framework for K–12 Science Education (National Research Council, 2012). The 2012 NSSME study followed 1 year later, and the NGSS were released in 2013. In this way, the 2012 NSSME provided baseline data for NGSS implementation. From 2013 to 2018, 39 states and the District of Columbia (DC) adopted the NGSS or NGSS-like standards (National Science Teaching Association, n.d.). By the time the 2018 NSSME+[1,2] was conducted, NGSS states accounted for over two-thirds of the nation's K–12 students. In this editorial, I summarize findings in these areas from analyses of data from the 2012 NSSME and the 2018 NSSME+ (Smith, 2020). I also try to explain the findings and suggest where the field may need to shift or concentrate its focus if the NGSS are to take hold in science classrooms broadly.

Is 5 years long enough to see the impacts of the NGSS? The answer depends on countless factors. The U.S. education system is complex and challenging to change. Unlike many nations, the United States does not have a single education system, but rather 50. Within the 50 states, local control varies widely. So, despite 39 states and DC adopting NGSS and NGSS-like standards in the first 5 years, the implications and outcomes of this phenomenon are unclear. As Figure 2 illustrates, states adopted the NGSS in a staggered manner. In this editorial, I refer to early adopters (the 16 who adopted between 2013 and 2015), late adopters (the 24 who adopted between 2015 and 2017), and non-adopters (those who had not adopted by the spring of 2018 when the 2018 NSSME+ collected data).

Whether it is too soon to look for impacts also depends on where one looks. We may hope to see changes in classroom instruction, but such changes are likely only if other aspects of the system have changed. Do teachers have more and different professional learning opportunities, ones that align with the NGSS? Do they have access to NGSS-

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[1]The plus symbol reflects an emphasis on computer science included in the 2018 study.

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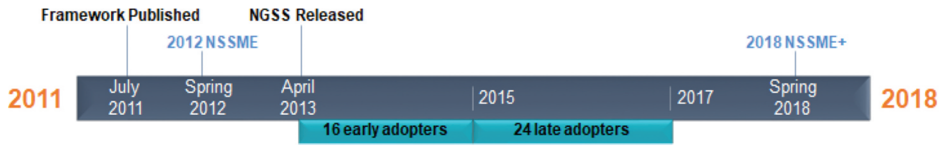

Figure 1. NGSS and the NSSME.

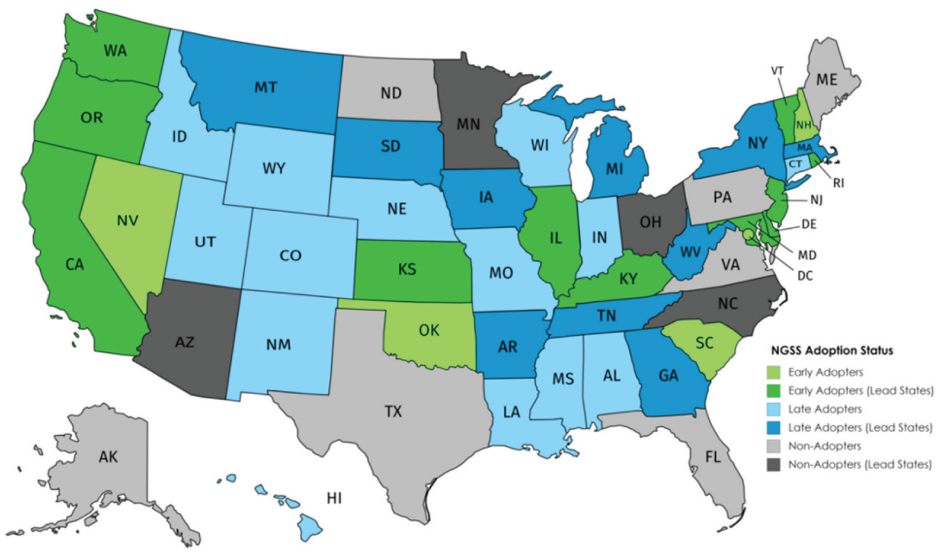

Figure 2. Adoption of NGSS or NGSS-like standards – August 2018.

aligned instructional materials? Do teachers feel well prepared to teach science, and do their beliefs about science teaching and learning align with the NGSS vision? Of course, other aspects of the system are important, but they are beyond the scope of the study. Two particularly influential ones are state assessment policies and practices.

Professional learning opportunities

The NGSS represent a major shift from earlier standards (American Association for the Advancement of Science, 1993; National Research Council, 1996), with the potential to "re-novice" much of the K–12 science teaching force (Hanuscin, Cisterna, & Lipsitz, 2018). Teacher preparation programs have an important role to play in ensuring that new teachers understand the NGSS vision, but the vast majority of in-service teachers will need professional learning opportunities. The 2012 NSSME and 2018 NSSME+ collected extensive data on teachers' access to and participation in professional development (PD).

The 2018 NSSME+ found that roughly four out of five secondary science teachers (i.e., middle school and high school teachers) participated in science-focused PD in the preceding 3 years, in contrast to three out of five elementary science teachers. Only about half of schools or districts offered any science-focused PD in the preceding 3 years. The data on participation are largely unchanged since 2012, although elementary teachers in adopting states were somewhat more likely in 2018 to have participated in some science-focused PD. The *quantity* of professional learning, however, is more troubling. At best, about a third of secondary teachers participated in over 35 hours of PD in the 3 years preceding 2018, and more than four in 10 elementary teachers had *none*. Even 35 hours, spread over 3 years, is not much considering current prominent instructional practices and the shifts that the NGSS entail.

The 2018 NSSME+ also asked about the characteristics of professional learning opportunities teachers participated in, although it is important to bear in mind that large proportions of teachers did not experience these opportunities with any depth (i.e., the opportunities were generally short in duration). Mostly, PD looked the same in 2012 and 2018, but the few apparent changes are encouraging, especially for elementary teachers. For example, these teachers were more likely in 2018 to have opportunities to work closely with other teachers from their school (34% of teachers in 2012 and 57% in 2018) and with other teachers who taught the same grade or subject, whether or not they were from their school (37% in 2012 and 47% in 2018). The characteristics of PD experiences for secondary teachers were largely unchanged. Looking at these data by adoption status, only one difference in 2018 stands out, but it is consistent with the NGSS. PD for teachers in early- and late-adopting states was more likely than PD for teachers in non-adopting states to heavily emphasize how science is done (e.g., developing scientific questions, developing and using models, and engaging in argumentation).

Teacher beliefs and preparedness

In general, science teachers' beliefs about effective science instruction align with the NGSS. In 2018, at least nine in 10 science teachers, regardless of grade range, agreed that: (1) teachers should ask students to support their conclusions about a science concept with evidence, (2) students learn best when instruction is connected to their everyday lives, (3) students should learn science by doing science, and (4) most class periods should provide opportunities for students to apply scientific ideas to real-world contexts. These data are encouraging. Less encouraging, two-thirds to three-fourths of science teachers agreed that students should be given definitions for new vocabulary at the beginning of instruction on a science idea, a practice that runs counter to the NGSS. More than half agreed that laboratory activities should be used primarily to *reinforce* ideas that students have *already learned*, and about one in three agreed that teachers should explain an idea to students *before* having them consider the evidence for that idea. Further, with one exception, the data on teacher beliefs did not vary by NGSS-adoption status. High school science teachers in adopting states were much less likely than those non-adopting states to agree that teachers should introduce vocabulary at the start of instruction.

Like their beliefs, teachers' feelings of preparedness can influence their science instruction. Among elementary teachers in self-contained classrooms in 2018, three-fourths felt very well prepared to teach mathematics, but less than a third felt the same level of preparedness for science instruction. Further, elementary teachers' perceptions of their preparedness for science instruction *declined* between 2012 and 2018, perhaps an indicator of the re-novicing mentioned earlier. These teachers' sense of preparedness for teaching specific disciplines of science (Earth, life, physical) also declined, and the declines were similar in adopting and non-adopting states. Overall, secondary teachers' perceptions of their preparedness to teach science were considerably higher than those of their elementary counterparts.

Decreases in preparedness among elementary teachers are evident regarding discrete tasks of instruction as well. For example, compared to 2012, these teachers were less likely in 2018 to feel very well prepared to (1) assess student understanding at the conclusion of a unit, (2) monitor student understanding during a unit, and (3) anticipate difficulties that students may have with particular science ideas and procedures. These data did not vary by NGSS-adoption status. In contrast, overall, no declines were evident among secondary teachers, whether regarding science content or instructional tasks.

Instructional materials

At the time of the 2018 NSSME+ (and even now), few NGSS-aligned materials were available according to the two organizations that conduct and publish reviews (*Free Reviews of K–12 Instructional Materials*, n.d.; *Quality Examples of Science Lessons and Units | Next Generation Science Standards*, n.d.). The situation has improved somewhat since then, especially in the middle grades due largely to the OpenSciEd initiative (*OpenSciEd—Free High-Quality Science Instructional Materials*, n.d.). However, 8 years after the release of NGSS, large gaps still exist.

In 2018, most science classes still based instruction on commercially published materials. In NGSS states, half or more of these science classes were using materials (textbooks, kits, or modules) published *before 2009*. In early adopting states, as many as two-thirds of elementary and middle grade science classes were using pre-NGSS materials. Elementary teachers in adopting states were much more likely than those in non-adopting states to alter their materials, picking some activities while skipping others. Further, they were more likely to pick and skip in 2018 than in 2012, perhaps trying to make their materials more NGSS aligned. Of course, this practice raises the possibility of making the materials less coherent at the same time.

Science instruction

The 2018 NSSME+ asked teachers about their objectives for science instruction and their class activities. In terms of objectives, science classes most frequently emphasized understanding science concepts in 2018, especially among secondary science classes (see Table 1). However, fewer than one in two secondary classes, and only one in four elementary classes, heavily emphasized students learning how to do science, which is surprising given how widely the NGSS were adopted at the time. The lack of emphasis on learning how to do engineering is also surprising.

Looking at these data by NGSS-adoption status, two differences emerge. Classes in adopting states were: (1) *less likely* than those in non-adopting states to focus on students learning vocabulary/facts and (2) *more likely* to place any emphasis on engineering (see Figure 3). Both differences are encouraging from an NGSS perspective.

Of course, emphasis matters little if science is not being taught or not being taught much. Too often, in self-contained elementary classrooms, science instruction loses the battle for instructional time. Although mathematics is taught essentially every day in these

Table 1. Science classes with heavy emphasis on various instructional objectives in 2018, by grade range.

	Percent of classes					
	Elementary		Middle		High	
Understanding science concepts	47	(1.7)	77	(1.8)	76	(1.8)
Learning how to do science (develop scientific questions; design and conduct investigations; analyze data; develop models, explanations, and scientific arguments)	26	(2.0)	46	(2.1)	41	(1.3)
Developing students' confidence that they can successfully pursue careers in science/ engineering	23	(2.0)	30	(1.9)	35	(1.5)
Learning science vocabulary and/or facts	27	(1.9)	37	(2.2)	32	(1.6)
Increasing students' interest in science/engineering	27	(2.2)	35	(2.1)	31	(1.5)
Learning about real-life applications of science/engineering	20	(2.1)	28	(2.0)	29	(1.2)
Learning test-taking skills/strategies	20	(1.5)	23	(1.8)	23	(1.4)
Learning about different fields of science/engineering	8	(1.9)	7	(1.2)	7	(0.8)
Learning how to do engineering (e.g., identify criteria and constraints, design solutions, optimize solutions)	8	(1.8)	10	(1.2)	5	(0.7)

classrooms, fewer than 20% of K–3 classes and only 35% of grades 4–6 self-contained classes have science instruction most or all days of the week. Surprisingly, self-contained classes in adopting states were even less likely than those in non-adopting states to receive science instruction all or most days (see Figure 4).

Disparities among subjects in instructional time are also evident. The average number of minutes per day typically spent on instruction in each subject in grades K–3 and 4–6 self-contained classes is shown in Table 2. In 2018, grades K–3 self-contained classes spent an average of 89 minutes per day on reading/language arts instruction and 57 minutes on mathematics instruction, compared to only 18 minutes on science. The pattern in grades 4–6 is similar except for a slight increase in science instructional time between 2012 and 2018. Classes in NGSS-adopting states spent no more time on science than those in non-adopting states.

Regarding how teachers use instructional time, three activities topped the list regardless of grade level: (1) explaining science ideas to the whole class, (2) engaging the whole class in discussions, and (3) having students work in small groups. Each occurred at least weekly in 75% or more of classes. Just over half of elementary and about two-thirds of secondary science classes included hands-on/laboratory activities at least weekly.

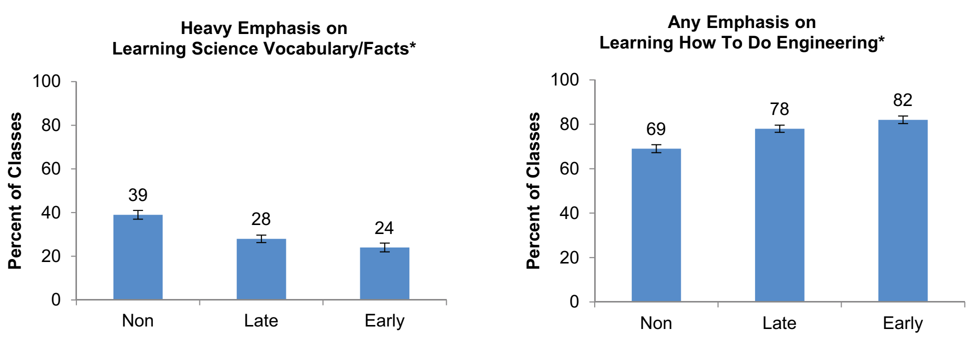

Figure 3. Instructional objectives (2018). There is a statistically significant difference between classes in non- and late-adopting states and between classes in non- and early adopting states (two-tailed independent samples *t*-tests, $p < 0.05$).

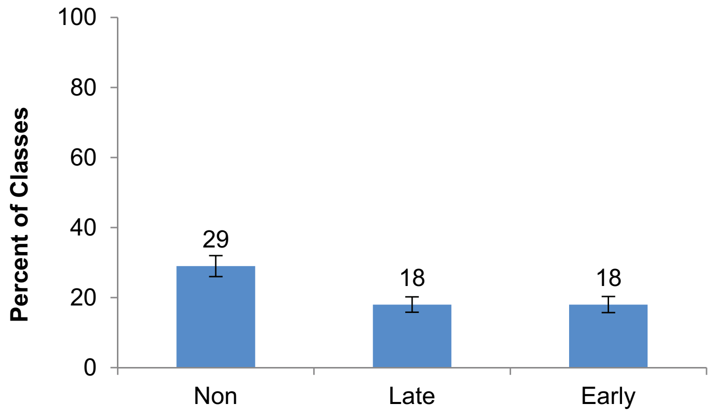

Figure 4. Self-contained elementary classes in which students receive science instruction all or most days (2018). There is a statistically significant difference between classes in non- and late-adopting states and between classes in non- and early adopting states (two-tailed independent samples *t*-tests, $p < 0.05$).

Table 2. Average number of minutes per day spent teaching each subject in self-contained classes,[a] by grade range.

	Number of minutes			
	2012		2018	
Grades K–3				
Reading/language arts	89	(1.7)	89	(1.7)
Mathematics*	54	(1.0)	57	(0.8)
Science	19	(0.5)	18	(0.5)
Social studies	16	(0.4)	16	(0.4)
Grades 4–6				
Reading/language arts	83	(2.2)	82	(2.4)
Mathematics	61	(1.4)	63	(1.6)
Science*	24	(0.9)	27	(0.8)
Social studies	21	(0.8)	21	(0.8)

[a]Includes only self-contained elementary teachers who indicated that they teach reading/language arts, mathematics, science, and social studies to one class of students.

*There is a statistically significant difference between classes in 2012 and classes in 2018 (two-tailed independent-samples *t*-test, $p < 0.05$).

Data on class activities point to some potentially encouraging signs related to the NGSS. Compared to classes in non- and late-adopting states, those in early-adopting states relied slightly less on the teacher explaining ideas and slightly more on students doing hands-on activities. In both early and late-adopting states, science classes were more likely to have students do project-based learning activities and to incorporate engineering into instruction. However, in each case, the differences are small.

Of particular interest from an NGSS-implementation perspective, the survey asked how often students engage with the practices of science, operationalized in more fine-grained survey items (Banilower, Hayes, Jaffri, & Egeland, 2016). Table 3 shows a subset of these items. The data suggest that students most often engaged in aspects of science related to conducting investigations and analyzing data, although even these are infrequent. In only one instance did more than half of classes engage students in a practice weekly or more

Table 3. Science classes in which teachers report students engaging in various aspects of science practices at least once a week in 2018, by grade range.

	Percent of classes					
	Elementary		Middle		High	
Organize and/or represent data using tables, charts, or graphs in order to facilitate analysis of the data	34	(2.1)	49	(2.3)	58	(1.5)
Make and support claims with evidence	32	(2.0)	51	(2.1)	50	(1.5)
Conduct a scientific investigation	36	(2.2)	48	(2.2)	50	(1.6)
Analyze data using grade-appropriate methods in order to identify patterns, trends, or relationships	27	(1.9)	43	(2.4)	47	(1.4)
Generate scientific questions	38	(2.2)	44	(2.2)	38	(1.8)
Develop scientific models – physical, graphical, or mathematical representations of real-world phenomena	19	(1.7)	34	(2.3)	34	(1.5)
Use multiple sources of evidence to develop an explanation	26	(2.0)	37	(2.3)	33	(1.6)
Select and use grade-appropriate mathematical and/or statistical techniques to analyze data	15	(1.4)	21	(1.8)	30	(1.6)
Determine whether or not a question is scientific	19	(1.6)	31	(1.8)	28	(1.5)
Use data and reasoning to defend, verbally or in writing, a claim or refute alternative scientific claims	17	(1.6)	28	(1.8)	27	(1.7)
Use mathematical and/or computational models to generate data to support a scientific claim	12	(1.2)	19	(1.4)	26	(1.3)
Identify the strengths and limitations of a scientific model –in terms of accuracy, clarity, generalizability, accessibility to others, and strength of evidence supporting it	12	(1.8)	22	(2.0)	22	(1.1)
Evaluate the strengths and weaknesses of competing scientific explanations	12	(1.3)	19	(1.7)	20	(1.6)
Determine what details about an investigation might persuade a targeted audience about a scientific claim	11	(1.2)	15	(1.6)	17	(1.3)
Construct a persuasive case, verbally or in writing, for the best scientific model or explanation for a real-world phenomenon	10	(1.1)	17	(1.5)	15	(1.1)

often. Students were engaged even less frequently in activities related to modeling, explanation, and argumentation. Overall, these data did not vary by adoption status.

Moving forward

Despite widespread adoption of the NGSS and NGSS-like standards, data from the NSSME+ point to few differences in science instruction compared to 2012. Further, the data from teachers in adopting states vary little from those in non-adopting states. Among the few differences, we do see encouraging signs. Among them, classes in adopting states were more likely to emphasize learning how to do engineering, and they were less likely to emphasize learning vocabulary and facts. In terms of instructional activities, classes in early-adopting states were less likely to rely on lecture and more likely to have students do hands-on activities. However, the data overall suggest that much work lies ahead to achieve the vision laid out in the Framework and the standards themselves. But what does that work look like?

Although national data suggest little movement toward the NGSS vision, some districts have focused immense, sustained effort on implementing the standards. The NSSME+ sample is large, but it is not large enough to detect the effects of these efforts. That should not diminish the importance of districts doing the hard work of planning for and implementing the NGSS. As a field, we should watch these districts closely and learn from them. They have much to tell us about what works and what does not. We would be wise to listen to them before we design large-scale efforts. Further, we need images of excellent NGSS-aligned instruction, and these districts are reasonable places to look for exemplars. Threedimensional teaching and learning are complex and often difficult to convey in words. A library of classroom video would be a valuable asset for pre-service teacher educators and for those who design professional learning opportunities for in-service teachers.

Depending on one's view of whether 2018 was too soon to look for changes due to the NGSS, the lack of change may or may not be surprising. Regardless, NSSME+ data both point to possible explanations and suggest areas where we should concentrate on reforms. One area is professional learning. Some teacher preparation programs have taken up the goal of preparing well-started beginners (e.g., Davis & Boerst, 2014; Mikeska, Anderson, & Schwarz, 2009), acknowledging that like other professionals, teachers must continue learning throughout their careers. Considering the substantial shifts associated with NGSS-aligned instruction, the rates of participation in science-focused professional learning can be described only as inadequate. If we expect teachers to orchestrate learning in a radically different way than they are used to, we have to create excellent opportunities to learn, and we have to give them time to participate in those opportunities. Both will require commitments (including financial ones) by schools and districts. We need to leverage existing structures for this work. One of these is discipline-focused teacher study groups, which almost half of the secondary schools already have in place. Of course, we need to think carefully about how to structure and facilitate these groups, making sure that each one either includes or has access to someone deeply familiar with the NGSS.

The lack of change might also be due in part to a lack of NGSS-aligned instructional materials. Recall that in adopting states, half of the science classes that rely on commercial materials were using ones published before 2009. These materials were almost certainly not aligned with the NGSS, leaving teachers who were inclined to change their instruction to assemble their own materials or adapt the ones designated for them. Anyone who has tried to develop NGSS-aligned materials will attest to how difficult it is. The fact that we expect full-time teachers to take on this work instead of supporting them with excellent materials is troubling at best. As mentioned earlier, OpenSciEd is making a big difference in the availability of materials for middle grade science instruction, but there is still much work to do.

The lack of instructional materials, coupled with the lack of NGSS professional learning opportunities, creates a climate where the burden of change falls almost entirely on the shoulders of teachers. Of course, teachers are always the ultimate change agents in the classroom, but with so little support, the demands are monumental. At the elementary level, the demands are even greater, especially for those who teach in self-contained classrooms. In choosing professional learning opportunities (assuming they have a choice), these teachers must balance their needs among all four core subjects. However, with accountability pressures so uneven among these subjects, we should not be surprised that these teachers spend so little time on science-focused opportunities. Accountability pressures also contribute to large disparities in instructional time among the core subjects. Given the circumstances in which they work, the declines in elementary teachers' perceptions of their preparedness to teach science make sense. Ironically, these teachers may be in the best position of all science teachers to make the NGSS vision a reality in their classrooms. The science and engineering practices draw heavily on reading, writing, and mathematics, subjects in which these teachers specialize. As we learn to support elementary teachers better in their NGSS implementation efforts, we need to acknowledge and leverage these assets.

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