Influences on NGSS Instruction: Curriculum, Professional Learning, and District Support

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Abstract:

The *Framework for K-12 Science Education* and Next Generation Science Standards advance a vision for science learning where students use disciplinary core ideas, crosscutting concepts, and science and engineering practices (SEPs) to make sense of phenomena and solve problems. There is an urgent need for curriculum materials that align to these standards, and for studies that rigorously evaluate materials to facilitate informed decision making about what will best support students' science learning. We report on our study of the Amplify Science Middle School curriculum (ASMS) and how it fits into the larger context of a district system, how it may be impacted by other system components (e.g., district support or teacher PL), and how these, in turn, may impact NGSS instruction in the classroom. This study was part of a larger randomized controlled trial that was conducted across 29 schools in four school districts with 59 seventh grade science teachers and their students. We examined the nature of curriculum use and NGSS instruction in treatment and control conditions via instructional logs and surveys. At the classroom level, we found that curricular features influenced which SEPs teachers engaged their students in more or less often. Across the district system, we identified two ingredients – district support and professional learning – that can also influence curricular uptake and implementation.

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Influences on NGSS Instruction: Curriculum, Professional Learning, and District Support

The *Framework for K-12 Science Education* (National Research Council [NRC], 2012) and the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) advance a vision for science learning where students use disciplinary core ideas (DCIs), crosscutting concepts (CCCs), and science and engineering practices (SEPs) to make sense of phenomenon and solve problems. Importantly, this vision expands how we think about science proficiency as not only what students know, but also how they can use and apply what they know (Harris et al., 2019). Over the past decade, this vision has transformed science education policy throughout the U.S., with forty-four states having adopted standards that have been influenced by the *Framework* alone or both the *Framework* and NGSS (National Science Teaching Association [NSTA], 2021).

Today, science teachers in many parts of the country are tasked with providing instructional experiences that will engage their students in using and applying the three dimensions of science proficiency. During instruction, the process of using and applying the dimensions is referred to as three-dimensional learning (NRC, 2012). Three-dimensional learning is the means through which students build proficiency with the knowledge-in-use goals of the NGSS performance expectations which are the target standards in many states.

Curriculum materials that align to these standards with a coherent approach and effective impact are critical to support teachers in providing instructional experiences that will engage their students in three-dimensional learning as called for by the *Framework* and the NGSS (Fortus & Krajcik, 2012; Penuel & Reiser, 2018; Pruitt, 2014). There are still few examples of "high-quality" curricula designed for the NGSS (Quality Examples of Science Lessons and Units, NextGenScience.org). However, as NGSS-designed curricula are becoming available and are adopted in school districts across the country, it will be of high value to examine the contexts in which they are implemented so that we can better understand what it takes for NGSS-designed materials to be implemented in schools, taken up by teachers, and ultimately be beneficial to students. Further, while some states and districts have prioritized implementing the NGSS, implementation was largely uneven across districts and grade levels (Gao et al., 2022). This information stands to be critically important for science education leaders and practitioners to be able to plan for successful curriculum implementation as well as to sustain the benefits of the implementation over the long haul.

In this paper, we report on our study of the implementation of an NGSS-designed middle school curriculum. We examined how the curriculum implementation fit into the larger context of the district system, how it was shaped by other system components (e.g., district support or teacher professional learning), and how these, in turn, may have impacted NGSS instruction in the classroom. Our overarching aim was to understand the relationships between various district system components – relationships between curriculum use and professional learning, and district support and professional learning – in the context of the curriculum implementation. Accordingly, our research was guided by the following question:

> How do science teachers take up NGSS-designed curriculum materials and in what ways do professional learning and district support interact with teachers' implementation of materials?

Our study sought to examine each of these three components of professional learning, district support, and NGSS-aligned curriculum materials to understand how they impact classroom instruction in 7th grade science classrooms. This investigation is an exploratory substudy of a larger RCT study (Harris et al., 2022).

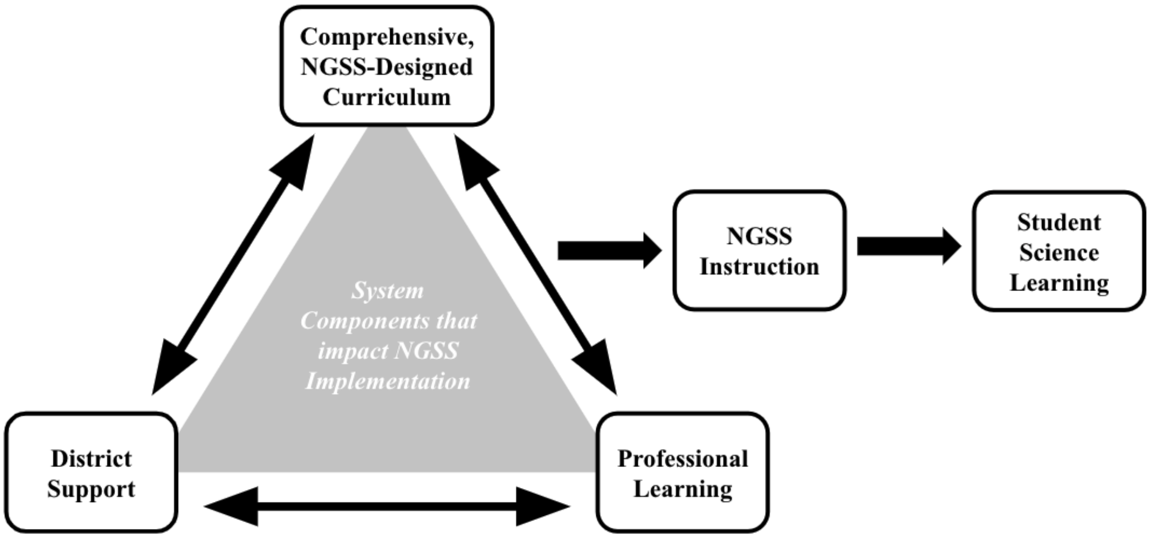
Theoretical Framework

It is widely recognized that realizing the vision of the *Framework* and NGSS will require a substantive change in instruction and assessment (NRC 2014; 2015). Such a significant shift in how science is taught in classrooms inevitably includes shifts in other areas of the larger district system. For example, research has shown that school leaders have a significant influence on the ability of teachers to enact instructional change (Stein et.al., 2016; Drago-Severson, 2007; Little, 2006; Mangin, 2007; Wood, 2007; York-Barr & Duke, 2004), and the availability of high-quality professional learning (PL) can encourage teacher uptake of new instructional standards and strategies (Desimone et al. 2002; Tyler et al., 2020).

We conceptualized NGSS instruction and the impacts of the district system on it via a socio-cultural lens. From this perspective, learning is situated and interactive (Lave & Wenger, 1991), where the learner will be influenced and learning will be impacted by their environment (legitimate peripheral participation). In this study the teacher is positioned as the learner, and the system components that may impact their learning and how they teach science, are drawn from three primary components of NGSS implementation: support of their district (e.g., funding, culture, administrator engagement, PL opportunities, or explicit policies for science teaching); the amount of NGSS-related PL they have received (either about the standards or strategies for teaching and learning those standards); and access to high-quality, comprehensive, and NGSS-aligned instructional materials. These system components draw from Stiles and colleagues' NGSS implementation report, *Framework for Leading Next Generation Science Standards Implementation* (Stiles et al., 2017). Their report provides a useful framework for analyzing the interaction of influences between system components at different levels such as individual classrooms, schools, or districts, as well as influences of learning goals like curriculum and standards. By utilizing this framework one can describe and examine the component parts of the larger system more fully. These primary system components interact with and support one another, and together they influence a distal outcome in this model, student learning (not reported on in this paper; see Figure 1). We are interested in understanding how district support efforts, professional learning opportunities, and an NGSS curriculum interact to influence NGSS instruction.

Figure 1

Curriculum, Professional Learning, and District Components in Interaction



The study sought to understand the relationships between these various system components: district support, professional learning, curriculum, and instruction. Using these three components as the lens through which we view our data can reveal how one of the first comprehensive NGSS-designed curricula is supported or constrained by various types of district support and professional learning opportunities.

Design and Procedure

The study reported here was part of a larger randomized controlled trial (RCT) which examined the efficacy of the Amplify Science Middle School curriculum (ASMS). The ASMS aims to provide students in grades 6-8 with opportunities to engage with disciplinary core ideas, crosscutting concepts, and SEPs over time to strengthen their science proficiency, and engage with anchor phenomena through multiple modalities. We investigated ASMS across a full year of 7th grade science. The RCT examined student learning outcomes and science instruction in treatment and control classrooms including teachers' instructional practices, attentiveness to SEPs, support for student sense-making of phenomena, and frequency of science instruction.

Setting and Participants

The study was conducted during the 2019-2020 school year with 59 grade 7 science teachers in classrooms across 29 schools in four school districts, who taught 5,699 students. Districts were in three states whose science standards were both informed by the *Framework* and the NGSS and took the form of NGSS-aligned performance expectations (PEs). The districts were of varying size (i.e., large, mid-size, and small) and served diverse student populations including multiple racial and ethnic groups, English Learners, and students who qualify for free or reduced-price lunch. See Table 1 for additional information on the students served within each participating district.

Table 1

Demographic Information for Students Served in Participating Districts

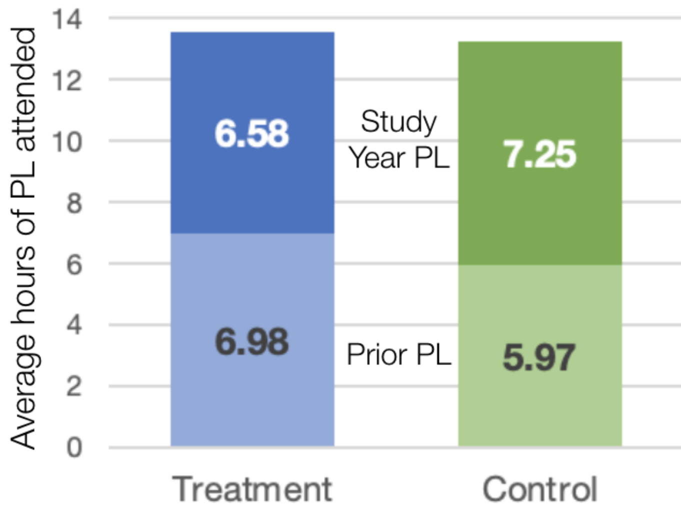
	Total Student Population	FRPL Enrollment	White	Black or African-American	Hispanic or Latino	Asian or Filipino	American Indian or Alaska Native	Native Hawaiian or Pacific Islander	Multi-ethnic or Two or more races
District 1	23,470	81.2%	9.4%	24.7%	50.3%	6.9%	0.1%	N/A	2.9%
District 2	40,503	47.1%	65.4%	6.5%	14.3%	4.6%	0.6%	0.1%	8.5%
District 3	8,546	20.3%	49.6%	2.8%	22.2%	17.1%	0.4%	0.3%	7.2%
District 4	122,933	57.6%	23.2%	7.9%	46.2%	13.3%	0.3%	0.4%	7.9%

Study Context

The broader project that this study is a part of was designed as a one year RCT in 7th grade classrooms. Schools within districts were paired based on their demographic characteristics and prior performance in state math and ELA tests and randomly assigned to treatment or control conditions. Treatment and control conditions were randomized at the school level, with treatment receiving the intervention, and control continuing with their business as usual science PL and curriculum, which in all districts was aligned to the NGSS performance expectations (PEs). All teachers in a school had the same assigned condition. Teachers in both groups implemented units on the same topics in physical and life science and followed their district science sequence and pacing. Teachers' survey responses showed that all participating teachers were roughly equivalent across multiple dimensions that may influence their NGSS instruction (e.g., teaching experience, current teaching assignment, amount of NGSS PL; see Figure 2). The RCT year 2019-2020 was interrupted by the COVID-19 pandemic in spring of 2020. In general, teachers were able to get through about two thirds of their planned instruction while schools were open. This study reports on findings from data collected from teachers about their in-person science instruction, prior to school closures.

Figure 2

Average Amount of Total Science or NGSS Professional Learning by Study Condition



To ensure that teachers in our analysis were comparable across state, district, school, and treatment and control groups, and because data collected for each teacher varied, we focused on a subset of teachers who met the following criteria: completed a survey at the end of the study year; completed at least four weekly logs (roughly equivalent to one month of science instruction); and were in schools that had at least one qualifying teacher at their paired school as well (e.g., at least one teacher in the treatment school and at least one teacher in its paired control school). This resulted in a subsample of 38 teachers in the quantitative analysis for this study; 20 in the treatment condition and 18 in the control condition. See Table 2 for details on the teachers and paired schools in the quantitative analytic sample. Qualitative data collection consisted of interviews with a sample of 14 treatment teachers, 4 principals from two districts, and 5 district science staff (at least one from each of the four districts). See the interview section below for more details on who completed these interviews.

Table 2

School Randomization Pairings Within Districts

	School Pair	# Treatment Teachers	# Control Teachers
District 1	A	1	1
	B	1	1
District 2	C	2	2
District 3	D	3	1
District 4	E	2	1
	F	2	2

	G	3	1
	H	2	2
	I	1	3
	J	1	2
	K	2	2

Curricular Context

Our study examined the implementation of the ASMS curriculum, which is specifically designed to address the shifts in instruction required by the NGSS. This NGSS-designed curriculum was developed by the Lawrence Hall of Science at UC Berkeley, and is part of the commercially available K–8 Amplify Science program. The curriculum package includes a digital platform for students and teachers along with physical materials for hands-on activities. Key components of the curriculum approach include centering each unit on an anchoring phenomena, incorporating authentic use of technology including simulations and digital tools for student sensemaking, and using a multimodal approach that provides students with exposure to key ideas through multiple modalities. Further, the curriculum includes a unique emphasis on literacy development, with explicit support for reading science text, writing science text and engaging in scientific discourse. For grade 7, ASMS consists of a full year of curriculum that spans six units, each focused on one of three science domains: Earth and Space, Physical, and Life Science. Treatment teachers received four full days of just-in-time professional learning (~6 hours each day) at key points in the school year to help familiarize them with the curriculum and help them understand how to integrate it into their classroom instruction.

Teachers in the control condition implemented their regular curricular units on Earth and Space, physical and life science topics. All districts and teachers were held accountable to their state standards which were aligned to NGSS Performance expectations, but the actual curriculum used varied. The range of enacted curriculum materials varied across schools, and all districts in the control condition used materials from many different sources (e.g., district-designed, teacher-developed, textbooks, open-source). Teachers in one district used a widely available redesigned curriculum for the NGSS; teachers in another used their own district-developed curriculum to address the NGSS performance expectations; and teachers in another district used a district-adopted textbook while some used an open-source, project-based NGSS curriculum. Initial analyses from the large-scale efficacy study of this NGSS-designed curriculum showed that there were increased gains in student learning outcomes (assessments of NGSS performance expectations [PEs]) in schools using the ASMS compared to those in the control group (Harris et al., 2022).

Data Collection

We used surveys and weekly instructional logs to capture the nature of curriculum use and NGSS instruction in physical science and life science in both conditions across districts. The logs and surveys included two broad categories of questions: enactment questions that focused on self-reporting of science instruction, modifications made to the ASMS lessons and activities (and reasons why), and successes and challenges encountered with the materials; and instruction questions that focused on frequency and depth of engaging students with the NGSS dimensions, instructional strategies employed, and instructional successes and challenges. To understand the instructional value and use of the ASMS within the classroom, as well as existing NGSS support in the districts and schools, we conducted interviews with treatment teachers, principals, and district administrators. Each of these data sources is described in more detail below.

Surveys

We administered two online surveys to all teachers in both treatment and control conditions. Both surveys were designed to take approximately 20-30 minutes. A background survey that focused on teachers' prior education, and their PL and science instruction experiences was developed and administered to teachers prior to their participation in the study. For the teachers included in the analytical sample, response rate was 100% for both the treatment and control conditions. Though not every teacher responded to every question in the survey, all 38 sample teachers did have responses to the background survey. An end of year survey measured teachers' science curriculum use, instruction questions focused on frequency and depth of engaging students with the NGSS dimensions, instructional strategies employed, and instructional successes and challenges, and enactment questions that focused on self-reporting of science instruction during the year. The survey also provided teacher self-reported information about NGSS-related district support and PL. Treatment teachers were also asked to report on their experiences with features of the ASMS, their satisfaction with training and follow-up support, their perceptions of the curriculum's impacts on student learning and achievement, and self-reported changes in their practice due to the intervention. The end of year survey was further informed by the National Survey of Science and Mathematics Education (Banilower et al., 2018) which addresses teacher beliefs, background, and experience, as well as instructional practices and resources. For the teachers included in the analytical sample, the response rate was 100% for both the treatment and control conditions for the end of year survey.

Weekly Instructional Logs

Weekly online instructional logs were completed by teachers in both conditions at the end of each week during life science and physical science instructional units. The average number of logs completed by the treatment group ranged from two to eleven logs for the two units, and for control the average number of logs was between six and seven for the two units. The logs were completed online, similar to a typical online survey, and were designed to be completed in 10-15 minutes. All teachers were sent an email toward the end of each week with a link to fill out their individual instructional log and were encouraged to complete the logs within three days of receiving the link. Instructional logs included two types of questions: enactment questions focused on self-report of lessons implemented that week, modifications made and why, and successes and challenges with the materials; and instruction questions focused on frequency and depth of engaging students with the NGSS dimensions, instructional strategies employed, and instructional successes and challenges.

Interviews

To complement the survey and instructional log data, we conducted semi-structured interviews (Patton, 2002) with district administrators from each district, as well as a randomly selected sample of treatment teachers and principals from all four participating districts. The interviews were approximately 30 minutes each and the interview protocol was designed to allow researchers to better understand the district context for science instruction, the system components that influence how and how often science is taught, the fit of the materials within classrooms, and teachers' experience implementing the ASMS. Each interview was audio recorded and transcribed verbatim. The full sample of interviews is outlined in Table 3 below.

Table 3

Interviews Conducted

Interview Numbers (23 total)	District 1	District 2	District 3	District 4	Total
Principal interviews	0	1	0	3	4
District interviews	1	1	2	1	5
Treatment teacher interviews	3	3	2	6	14

Analyses

To answer our research question, *How do science teachers take up NGSS-designed curriculum materials and in what ways do professional learning and district support interact with teachers' implementation of materials?*, our team analyzed both quantitative and qualitative data from teacher surveys, weekly instructional logs, and interviews to better understand treatment teachers' experiences with ASMS, as well as to compare the treatment and control conditions. We conducted interviews with a sample of treatment teachers, school principals, and district administrators from each district to get their perspective on NGSS instruction in their classroom, school, or district. The overall sample for the specific study presented here included 38 teacher participants (of the total 59 participants), five district administrators, and four principals. Of these 38 teacher participants, 20 were in the treatment condition and 18 were in the control condition.

First, we analyzed data from teacher surveys and instructional logs with a particular focus on responses to items about their NGSS-related science practices and system components that might be associated with implementation of those practices (e.g., curriculum use, district support, and PL). Frequency distributions were run for each survey and log item. The related items were combined to form a subscale through a psychometric analysis for the survey responses. A single-level regression model was used to estimate the treatment and control differences on the survey scales and log items. The standard error of estimate that allows for intragroup correlation was used to account for the clustering effect of data (teachers nesting within schools). Teacher background information such as the number of years teaching science was also included as the covariates in the model to improve the precision of the estimates. For the descriptive purpose, we also examined the score difference by district and the level of the professional learning experience.

Following the initial analyses of the log and survey data, qualitative analyses of interview data were completed. A priori codes were created that aligned with quantitative findings to identify relevant data more easily and to facilitate triangulation across data sources. Descriptions of the system components influencing NGSS science instruction are primarily based on descriptive statistics from teacher surveys and logs, and a systematic deductive coding and analysis of the interview data based on the study's theoretical framework. Two closely related but slightly different coding schemes were created, one for use in analysis of the principal and district personnel interviews and the other for use in the analysis of the teacher interviews. Interview transcripts were coded using NVivo qualitative analysis software. Researchers met frequently to discuss and iteratively refine the coding frameworks. The final coding frameworks focused on three primary elements: ASMS curriculum enactment, NGSS enactment in middle school science, and system factors that may influence that enactment. Once the coding frameworks were finalized, researchers analyzed a subsample of interviews as a group, using a priori and emergent coding (Strauss & Corbin, 1997). Once agreement was reached on the use of the coding frameworks, a single researcher coded all of the teacher interviews, and a separate researcher coded the district and principal interviews, each using the respective coding framework. After initial coding, a secondary analysis was conducted to determine the frequency of each code in the dataset, and code co-occurrence was calculated to uncover patterns in teachers' interviews, and separately for district and principal interviews, and highlight latent connections that existed between codes. All interview excerpts that had substantial or theoretically meaningful (i.e., explanatory) code co-occurrence were independently reanalyzed by researchers using emergent coding to identify themes in the data.

Findings

Curriculum

We report on treatment teachers' instruction supported by the ASMS curriculum in two areas: literacy-related science activities and use of science and engineering practices.

Literacy-related Science Activities

Evidence from weekly logs suggests that the ASMS curriculum supported teachers in engaging their students in literacy-related science activities. As shown in Table 4, we found that treatment teachers provided their students with significantly more NGSS-aligned instructional opportunities, especially literacy-related science activities. Treatment teachers spent significantly more time having students read science text, write in science notebooks, and communicate scientific thinking during weeks that they completed logs.

Table 4

Frequency of Literacy-related Science Instructional Opportunities by Study Condition

Which of the following instructional opportunities, if any, did you provide in your class this week? (Mark all that apply.)	Tx (adjusted mean)	Cx (adjusted mean)	Diff	SE	*p*
Read science text	0.706	0.444	**0.262**	0.0377	**<.001**
Write in science notebooks	0.851	0.587	**0.263**	0.0696	**0.001**
Communicate scientific thinking	0.839	0.602	**0.237**	0.0443	**<.001**

In interviews with treatment teachers, the emphasis on literacy development was seen as a unique strength of the ASMS curriculum, developing skills for students that they can use in other classes, as described by one teacher here:

> I think that's [ASMS's] greatest strength is that at some times it feels kind of like an English course, teaching them how to write text dependent analysis or arguments and science. I think that's a really big strength because if students do read and write, then they're going to be successful with their school.

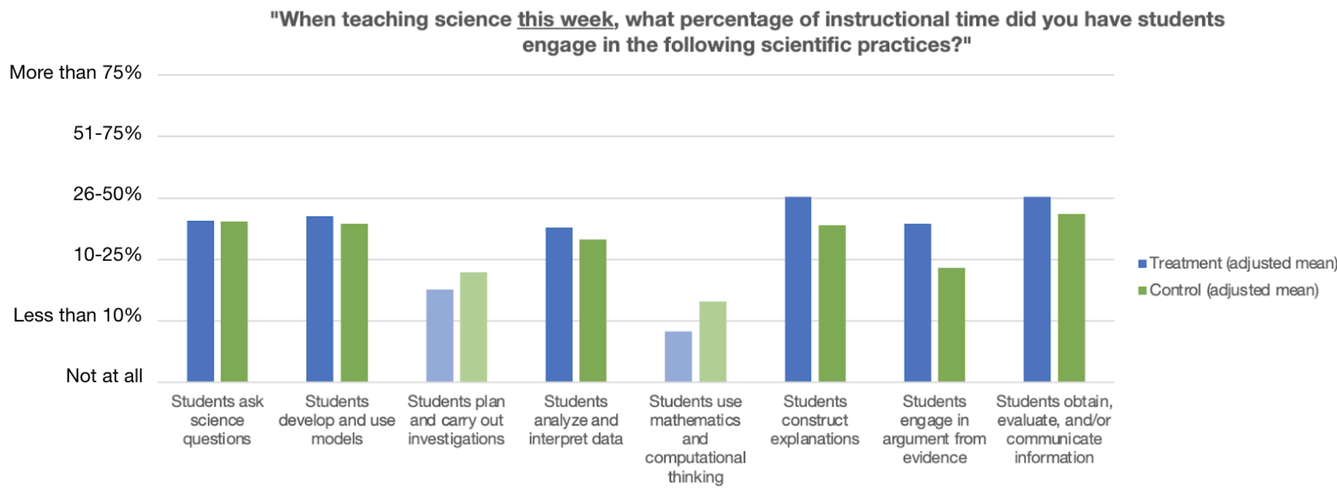
Science and Engineering Practices

In our analyses of the weekly logs, we also found differences between treatment and control teachers on the average percent of their instructional time devoted to many NGSS practices. As shown in Figure 3, treatment teachers spent more time having students engage in six of the eight SEPs, with the largest difference in time on *engaging in argument from evidence* and *constructing explanations*. Interviews indicated that teachers were taking up the practices that were emphasized most in the curriculum, which helped them engage their students in these practices more often than counterparts in control condition classrooms. Many teachers discussed the "Reasoning Tool" which guided students through making a claim, providing evidence, and writing out their reasoning, as being particularly valuable. One teacher explained, "I loved the writing piece where they had to do the claim, evidence, reasoning, and it really got them to truly understand that." ASMS's tools are designed to provide explicit engagement in these SEPs. According to another teacher:

> The tool that we use for writing the claim evidence reasoning... was really, really helpful... That's one of the hardest things that we always struggled with… They can write the claim. They can find the evidence, but then, putting it back together with reasoning... That reasoning tool really helped.

Figure 3

Average Frequency of Student Engagement in Science and Engineering Practices by Study Condition



Control teachers, meanwhile, spent more time on *planning and carrying out investigations* and *using mathematics and computational thinking*, which received less emphasis in the ASMS curriculum.

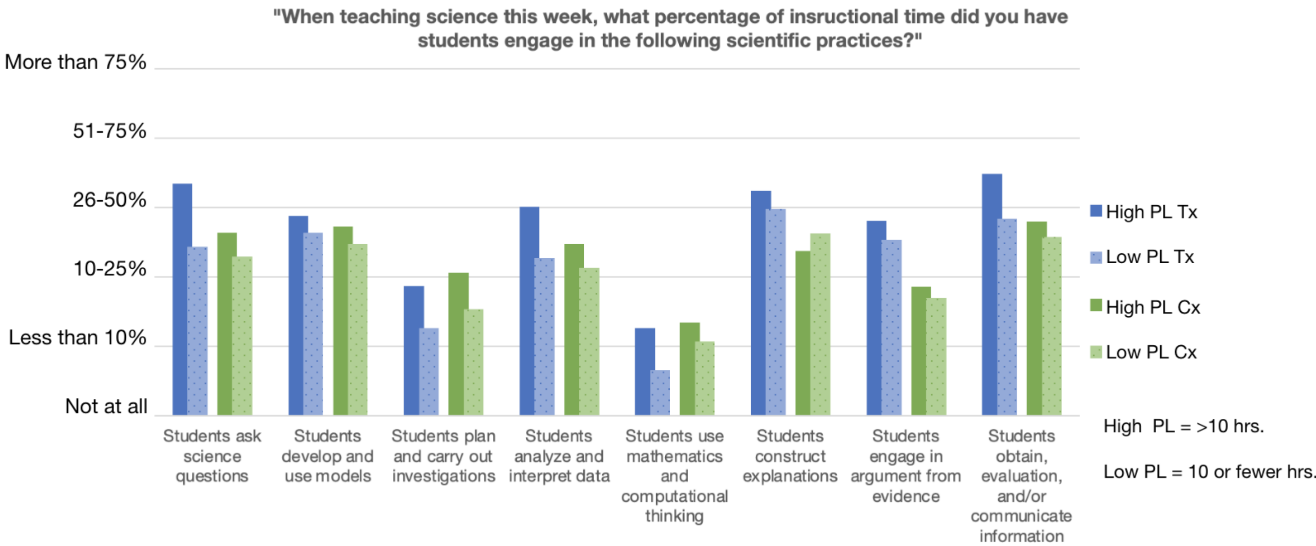
Professional Learning

For the next part of our analysis, we examined the impacts that professional learning (PL) had on teachers' science instruction across both conditions. We grouped teachers within each study condition by the total hours of science or NGSS PL they participated in *prior to* or *during* the study year (see Figure 2). To better understand the potential cumulative impact of PL received and curriculum used, we looked at the instructional log data and then compared teachers.

Figure 4 shows that teachers who had a greater amount of PL almost always indicated engaging their students in the SEPs more often than the teachers who had less PL. This trend held true not only for treatment teachers, but also control teachers who did not have access to the ASMS curriculum. The only exception to this was the SEP *constructing explanations* among control teachers; control teachers with lower reported PL indicated that they engaged students in more of that SEP (*constructing explanations*) than teachers with more reported PL hours.

Figure 4

Average Frequency of Student Engagement in Science and Engineering Practices by Study Condition and Amount of Teacher Science Professional Learning



Treatment teachers (see blue bars in Figure 4) who reported high PL combined with treatment (ASMS curriculum) also reported engaging students in all of the SEPs more often than control teachers, even those control teachers who had high levels of PL received. During interviews, one treatment teacher reasoned that teachers who have done more PL likely have a deeper understanding of the standards and know what they ideally should be emphasizing in instruction, but that still, "They [teachers] don't know how to do that. Everybody understands that's true. But how do I make that shift?" This indicates that teachers may grasp that it is important to engage students in SEPs, but may lack the tools or support through resources like curriculum to put what they learn in their PL into practice in their classrooms. Figure 4 shows that for treatment teachers, the high PL combined with ASMS curricular resources provided a substantial boost in their emphasis on the SEPs.

District Support

The final aspect we examined was the role district support played in NGSS instruction. Here we report findings related to curriculum and PL.

Balanced District Support

In interviews, district staff acknowledged that all teachers should have opportunities to engage in high-quality professional learning that deepens their knowledge and builds their capacity. They also commented that all teachers should have guaranteed and equitable access to rigorous standards-based curriculum. Importantly though, district leaders understood how they need to provide teachers with both quality curriculum and PL. In other words, they understood how neither curriculum nor PL in isolation were enough to see standards implemented. In particular, one district leader commented that, "You can't reach high-quality instruction with just professional learning absent of materials alone. You have to have that combination." In summary, we found that district leaders by and large understood the necessity for *both* of these components in combination with each other for supporting quality NGSS-aligned instruction.

However, interviews with teachers revealed that, in reality, teachers often had access to only one or the other of these system components (PL or curriculum) but rarely both in combination with each other. One teacher described having very little, if any, PL opportunities through the district, but did have access to NGSS-designed curriculum (in this case ASMS) and PL as a condition for the study. This teacher explained that science teachers in general did "not have [PL] through the district. Our school met once or twice a month in our grade level content areas and just that kind of stuff. And every time I would meet with them, I would just be like, 'I'm good. I got Amplify.'" As described earlier, while this confidence is positive, we have found that curriculum alone is not sufficient.

On the other end of the continuum, another teacher in a different district described having lots of PL opportunities but no vehicle (like curriculum) for them to put their skills into practice. This teacher shared that, "I have lots of professional development pertaining to [the standards] and how to teach them. I feel like I have the skills available. I just haven't been able to put them to use personally yet." This teacher's experience expresses the reality that curriculum access is an essential component of NGSS implementation; with lots of PL but absent the curriculum, this teacher felt they were not fully realizing the essence of teaching NGSS.

District Supported Alignment

In addition, interviews revealed a need for alignment between classrooms within the same school and across schools in the same district. Many teachers reported wide variation in the instruction students received from classroom to classroom, even within the same school and grade level. Some teachers felt like they were left to teach NGSS on their own and were constantly reinventing the wheel. For example, in response to a question about their NGSS instruction, one teacher explained that:

> Aligning content to NGSS has been a challenge because our textbooks are not designed for that. My district has not had good coordination across sites on what topics each grade level is teaching. We don't get to collaborate with other middle school science teachers, and there's not a strong push from leadership on what specific storylines we should be teaching. We've been figuring it out on our own.

An assumption underlying this quote is that alignment across classrooms may better ensure that all students were receiving similar instructional opportunities. The quote describes what happens when this alignment and coordination is lacking; without textbooks aligned to the curriculum, a lack of coordination across sites, lack of collaboration time with other middle school science teachers, and no direction from leadership about specific storylines, teachers needed to figure out NGSS on their own.

Interviews with district staff revealed a broad consensus that a comprehensive, NGSS-aligned curriculum was key in achieving this alignment. One district staff member explained that adopting materials like Amplify created unity across teachers and achieved consistency across grade levels. "Things are changing so fast that... because of the adoption [of the NGSS] and because of the [ASMS] project… I think that will help unify our teachers and get consistency across the grade levels." However, district leaders also acknowledged a constraint that arose in teacher interviews as well, some teachers preferred to have the autonomy in deciding what and how to teach science that came with less alignment. District staff reported receiving some pushback from these teachers. One teacher described how having autonomy over what to teach means that they can decide what is best for their students, saying "The pluses are that I have a lot of autonomy if I want to teach a topic and I decide what's best for my students." While district staff have some level of control over curriculum and PL (within the bounds of larger expectations and funding), some reported that they are still somewhat constrained by the nature of working with people who have different preferences and beliefs. This line that districts must tread, between district control and teacher independence, emphasizes that the role of the district is to balance different priorities, needs, and financial considerations.

Discussion

Implementing today's vision for science education requires purposeful attention to a range of district system components, including curriculum materials, professional learning, and district-level leadership. The implementation of the NGSS is complex for teachers, schools, and districts alike. Each component presents unique challenges but also potential opportunities for teachers and district leaders who are working to implement this ambitious vision of science instruction. As such, we must rethink how each of these three components work in isolation and their interactions. Teachers face myriad challenges in trying to implement these standards in their classrooms, and they cannot bring about systemic change on their own.

Our findings show that curricular features intended to support teachers in engaging students with the SEPs matter for instruction. Specifically, we found that teachers using the ASMS curriculum took up the support in the materials to integrate reading, writing, and communication into their science instruction. These supports were pervasive in the units. Accordingly, teachers reported that they engaged their students in SEPs like argumentation and constructing explanations much more often than did teachers who were using other materials. However, we acknowledge that teachers may not be able to engage students equally and deeply in <u>all</u> aspects of the NGSS in a single week, unit, or even school year, even with an NGSS-designed curriculum. Also, NGSS-designed curricula vary in their attention to SEPs and at this time there is little research available to provide guidance on the best weighting of SEPs for supporting three-dimensional learning.

Another key finding from this study is that an NGSS-designed curriculum with accompanying PL on the NGSS gives instruction an extra boost. We found that uptake of the NGSS-designed curriculum can lead to more implementation of some of the various elements of 3D instruction than in control classrooms. Noteworthy is that when the curriculum implementation was coupled with at least ten hours of PL, we found that teachers increased their instructional time on the SEPs in comparison to teachers in the treatment condition who had a lower dose of PL, and to the teachers in the control condition.

These findings suggest that district science leaders should not rely on an NGSS curriculum alone for equipping teachers for NGSS instruction; PL appears to be a beneficial partner for successful implementation. This aligns with the growing research base on curriculum-based professional learning that shows that PL anchored in high-quality curriculum materials stands to have a direct positive impact on teaching practice compared to more general PL (see for example, Short & Hirsh, 2020). Also noteworthy is that in the larger RCT study described earlier but not reported in this paper (Harris et al., 2022) we found that, in fact, the ASMS units did significantly impact student learning outcomes. This finding, when considered in light of the findings on curriculum implementation and PL reported in this paper, suggest that an NGSS-designed curriculum that has shown promising results for student learning outcomes could be even more effective for teachers and students when paired with PL.

Regarding district level support, we found that district leaders recognized the value of professional learning coupled with curriculum materials, but that district realities shaped by a range of factors (e.g., policies, priorities, funding allocations, etc.) interfered with realizing the ideal. For example, a district's implementation of curriculum can be constrained in consequential ways, such as by teachers' desire for autonomy, and the extent to which PL can be added to support implementation may be limited by budget and time. What is clear is that balancing investments between curriculum and PL and achieving coherence within and across all members of the district system is a challenge. It is the district's role then to maintain balance between these two priorities, and not invest too heavily in one at the expense of being able to provide the other. An implication is that when trying to find balance, district leaders should keep in mind that there needs to be some coherence so that teachers are effectively supported and professionally prepared, but that they need to also support the professional autonomy of teachers and treat them as the experts they are by allowing them to make modifications to their instructional materials if needed.

Overall, our findings highlight how curricula, even when it is comprehensive and designed specifically for the NGSS, requires other system components to work in tandem to fully realize the potential of the materials for teachers and students. This is informative for the science education field and for leaders within district, local, and state education systems as it is important to know that investing in only one component or not investing evenly across these components, can lead to issues that may inhibit implementation. Further, by investigating the impacts that curricula, PL, and district support have on NGSS instruction and interactions between these three components, professional development providers, curriculum developers, and school districts will be able to better understand how best to support teachers together, rather than relying on a siloed or disconnected approach to curriculum implementation.

Identifying necessary supports to enable teachers to effectively take up and implement NGSS-designed materials will support the broader goal of the *Framework* to enable more students to have opportunities to engage in science and become scientifically literate. The curriculum materials that teachers bring to life in their classrooms is just one of the factors that influence high-quality science instruction. Understanding how other system components such as district support, curriculum design, and PL can influence instruction will help to support teachers as they work to bring more authentic science learning aligned with the NGSS to all of their students.

References

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). Report of the 2018 NSSME+. Chapel Hill, NC: *Horizon Research, Inc.*

Drago-Severson, E. (2007). Helping teachers learn: Principals as professional development leaders. *Teachers College Record*, *109*(1), 70-125.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis*, *24*(2), 81-112.

Fortus, D., & Krajcik, J. (2012). Curriculum coherence and learning progressions. *Second international handbook of science education* (pp. 783-798). Springer, Dordrecht.

Gao, N., DiRanna, K., Chang Fay, M.T. (2022). The Impact of COVID-19 on Science Education: Early Evidence from California. Public Policy INstitute of California. Retrieved from: https://www.ppic.org/publication/the-impact-of-covid-19-on-science-education/

Harris, C. J., Krajcik, J., Pellegrino, J. & DeBarger, A. H. (2019). Designing knowledge-in-use assessments to promote deeper learning. *Educational Measurement: Issues and Practice*. 38 (2), 53-67.

Harris, C. J., Feng, M., Murphy, R., & Rutstein, D. W. (2022). *Curriculum materials designed for the Next Generation Science Standards show promise: Initial results from a randomized controlled trial in middle schools*. WestEd.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Little, J.W. (2006). *Professional community and professional development in the learning-centered school*. National Education Association. Retrieved from www.nea.org.

Mangin, M. M. (2007). Facilitating elementary principals' support for instructional teacher leadership. *Educational Administration Quarterly, 43*(3), 319-357.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.

National Research Council. (2014). Developing assessments for the Next Generation Science Standards. National Academies Press.

National Research Council. (2015). Guide to implementing the next generation science standards. National Academies Press.

National Science Teaching Association [NSTA], 2021. https://www.nsta.org/

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.

Penuel, W. R., & Reiser, B. J. (2018). Designing NGSS-aligned curriculum materials. *Committee to Revise America's Lab Report.*

Pruitt, S. L. (2014). The Next Generation Science Standards: The features and challenges. *Journal of Science Teacher Education, 25*(2)*,* 145–156.

Quality Examples of Science Lessons and Units. (n.d.). https://www.nextgenscience.org/resources/examples-quality-ngss-design

Roth, W. M., & Lee, Y. J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186-232.

Short, J., and Hirsh, S. (2020). *The Elements: Transforming Teaching through Curriculum-Based Professional Learning*. New York: Carnegie Corporation of New York.

Stein, K. C., Macaluso, M., & Stanulis, R. N. (2016). The interplay between principal leadership and teacher leader efficacy. *Journal of School Leadership*, *26*(6), 1002-1032.

Stiles, K., Mundry, S., & DiRanna, K. (2017). *Framework for Leading Next Generation Science Standards Implementation*. San Francisco: WestEd.

Tyler, B., Estrella, D., Britton, T., Nguyen, K., Iveland, A., Nilsen, K., Arnett, E., & Valcarcel, J. (2020). What education leaders can learn about NGSS implementation: Highlights from the Early Implementers Initiative. WestEd.

Wood, D. (2007). Teachers' learning communities: Catalyst for change or a new infrastructure for the status quo? *Teachers College Record 109*(3), 699-739.

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research, 74*(3)*,* 255-316.

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