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Increasing the Circle of Light on Professional Development

The Case of the Next Generation of Science Exemplar Facilitator Learning

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A Final Report to the
Next Generation of Science Standards Exemplar Project

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Increasing the Circle of Light on Professional Development: The Case of the Next Generation of Science Exemplar Facilitator Learning

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Introduction

For at least the past 30 years, there has been increasing interest and investment in teacher professional development. This has included funding for expanded and expansive programs of professional learning for teachers and administrators, the commitment of more time to such efforts, and a more ambitious conceptualization of professional development as one piece of the educational system that is either supported or thwarted by its (mis)alignment with other important levers, including personnel or curricular policies and practices. In the cacophonous landscape of national, state, and local discourse, educators, policymakers, and scholars have conducted research, set standards, and offered opinions about myriad questions: What does research tell us about effective professional development? What state and local policies are best suited for supporting high quality professional learning opportunities? What kinds of learning opportunities do teachers really need?

These are all compelling questions, which have been accompanied by a great deal of debate. But despite considerable investment in research and development, it has proved difficult to definitively answer them.[3] While report after report has described best practices, components, and professional development models (e.g., Darling-Hammond et al., 2017; Desimone, 2009, 2011; Hill et al., 2013; Wilson, 2013), well-resourced quasi-experimental studies have failed to demonstrate that these features are consistently associated with measures of program effectiveness like changes in teacher practice or increases in student test scores (e.g., Desimone et al., 2002; Garet et al., 2001, 2008, 2010, 2016; Hill & Ball, 2004; Institute for Education Sciences, 2016; Kennedy, 2016; Kraft et al., 2018; Roth et al., 2011, 2019). One possibility is that we are chasing a chimera, and that effective professional development does not fit comfortably into an "intervention framework," which conceptualizes the teacher development problem as both short term and focused on "fixing" teachers. Another possibility is that the oft-mentioned aspects of high quality professional development – coherence, teachers' active engagement, sufficient duration, collective participation, and content focus – highlight a set of

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[3] We use "high quality" here as a broader term than "effective" professional development, as effective has been too often associated with a narrower definition of quality PD as "causing" higher standardized student test scores. While increased student learning is one outcome of high quality professional learning, we need more robust and broad measures of student learning and other consequences of high quality professional learning, including school level outcomes like professional learning communities or individual teacher outcomes like teacher confidence or capacity.

surface level abstractions that fail to explain the underlying mechanisms or processes that lead to teacher learning and change. Alternatively, lists of best practices do not sufficiently account for the influence of context, for example, the culture of the schools in which teachers then try to apply ideas from professional development. That is, while empirical propositions like these may be warranted, they are insufficient to predict when professional development will produce significant changes in teachers or students.

This puzzle -- what can we say definitively about professional development -- matters. It is broadly understood that teaching requires on-going professional learning, and that mounting effective professional development for the four million teachers who comprise the workforce represents the largest single on-going professional education challenge in the country. Millions of dollars are invested annually in PD by U. S. schools, districts, institutions of higher education, research projects, foundations, and individual teachers. Thinking clearly about this puzzle has significant implications for the U. S. educational system and improvement efforts.

The purpose of this paper is to present a thick description of a professional development program for professional development facilitators. The goal is to not to test the core features mentioned above and discussed in what follows, nor is it to prove that this particular case leads to increases in student test scores. We take our lead from Geertz (1973) instead, who explained: "Believing with Max Weber that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it to be therefore not an experimental science in search of a law but an interpretive one in search of meaning" (p. 5). Our goal is to describe the meaning that participants make of professional development, by exploring the following questions: What do facilitators-in-training report learning in one professional development program? From the participants' perspectives, how is that learning related to the experiences constructed for them? What light does this case shed on the puzzle of understanding professional development?

The Next Generation of Science Exemplar Project (NGSX) is a professional learning system that has evolved over time to support teachers, principals, and teacher leaders in learning about the Next Generation of Science Standards (NGSS) and becoming prepared to use, adapt, and develop materials to support the steady, on-going reform of science teaching. Drawing on the digital documentation of NGSX, program artifacts, observations of classroom and professional development in two states, and ethnographic interviews with various participants and stakeholders, the case describes the complexities of professional development leader learning in the context of ambitious science education reform. A secondary goal of this paper is to contribute to the modest but growing literature on the preparation and practices of the leaders or facilitators of professional development. As Koellner et al. (2011) note:

> A central factor of a sustainable, scalable PD program is the ability to prepare leaders who can implement the program with integrity, adapting it to local contexts while maintaining consistency with core principles. Regrettably, developing the knowledge base and leadership skills of local instructional leaders is often a missing step in educational reform efforts. (p. 115)

Given the magnitude of the teacher workforce, it is imperative that we understand what it takes to mount high quality efforts to support the improvement of practice at scale (National

Academies of Sciences, Engineering, and Medicine (NASEM), 2015). This requires understanding the materials, learning opportunities, and on-going support needed for all teachers *and* the materials, learning opportunities, and support needed for the personnel who will teach those teachers. It also requires a conception of "scaling up" that allows for the contextualized nature of teaching and educator – in this case, facilitator – learning. This entails creating learning opportunities that are adaptable, and that shift authority, knowledge, and ownership from external actors to the teachers, facilitators, and administrators in local schools who are ultimately responsible for instruction (Coburn, 2003) and who will remain in the schools long after the professional development event or intervention is over.

We begin with a brief overview of three relevant bodies of literature: (1) on-going science education reforms; (2) literature on professional development; and (3) literature on the professional development of facilitators. These constitute an important backdrop for this study, which examines one ambitious effort to prepare professional development leaders for reforming U.S. science teaching and learning.

Background
Science Educator Professional Development in the Age of the Next Generation of Science Standards

Science Education Reform

By the early 2000s, every state in the U.S. had developed student learning standards for pre K-12 public schools in academic core subjects, as well as operationalized definitions of student proficiency at specific grade levels. Not surprisingly given local and state control of education in the U.S., there was variability both in the learning standards and in expectations for proficiency. This lack of agreement was seen as problematic for reformers, policymakers, and educators, contributing to the on-going inequities in how well U.S. youth are prepared for pursuing careers, attending college, and engaging as thoughtful citizens. Students crossing state lines could not be sure that they were prepared for the curriculum they would encounter in their new schools, professors in higher education could not count on what basic skills and knowledge students brought to their studies, nor could employers count on an appropriately educated workforce.

Given this challenge, in 2008, the National Governors Association (NGA), the Council Chief State School Officers (CCSSO), and Achieve recommended that states "upgrade state standards by adopting a common core of internationally benchmarked standards in math and language arts for grades K-12" and set a process in motion that led to the creation of those standards in June 2010. Shortly after that a consortium of 26 states, the National Science Teachers Association, the American Association for the Advancement of Science, the National Research Council (NRC), and Achieve developed the Framework for K-12 Science Education (National Research Council, 2011). Subsequently, a 40-member writing team developing the Next Generation of Science Standards (NGSS) in a process overseen by the National Research Council (NGSS Lead States, 2013).

There is a long history of efforts to reform science education (e.g., Atkin & Black, 2004; DeBoer, 2014; Rudolph, 2002, 2019). Educators have wrestled with how to handle the explosion

of knowledge in the sciences, and the proliferation of new fields, as well as the challenge of teaching students how to think scientifically and to understand scientific inquiry, not simply to master an ever-increasing heap of facts or a simplistic set of steps of "scientific inquiry." Reformers have worked to support elementary teachers, who often have very little experience with the sciences themselves, secure sufficient time in the curriculum for learning science, and to engage students in substantial, relevant, and meaningful learning. Educators have debated about which of the myriad sciences under the umbrella of the biological and physical sciences ought to be core – learned by all citizens – and which should be optional, pursued by students with special interests.

The NGSS represents the culmination of years of deliberation, debate, and research on what science should be taught in schools, and what aspirations we ought to have for all students' learning. And while the NGSS description of what students need to know and be able to do is not entirely new, it departs in significant ways from the typical science curriculum that most U.S. students have encountered. Organized around three dimensions — Science Practices, Cross Cutting Concepts, and Disciplinary Core Ideas (DCIs) — the NGSS paints a picture of science education that insiders refer to as 3-D (dimensional), and involving a shift from "learning about science . . . . to figuring out science." Science, from this perspective, is not meant to be taught in a vacuum but rather in context, with students working on genuine problems in ways that engage them in scientific thinking ("practices" in the language of the NGSS), while they apply and expand their knowledge of scientific content and concepts.

Twenty states and the District of Columbia have adopted the NGSS; another 24 states have revised their standards in light of the recommendations in the *Framework*. Science educators and reformers are well aware of the challenges associated with moving away from traditional science instruction to this vision of science teaching and learning; research and development on systemic, standards-based, and curricular reform have generated a rich literature on the complexities of changing instruction (Sykes & Wilson, 2016). The effort requires substantial resources: material resources like new curriculum and assessments; new human resources – enhancing teacher knowledge and skill, as well as preparing teacher leaders, science teacher educators, coaches, mentors, and school leaders; and new social resources, including networks of educators committed to change (Cohen et al., 2003). The science education community, including professional organizations like the National Science Teachers Association, the Board of Science Education of the National Academy of Sciences, Medicine, and Engineering, the National Association for Research in Science Teaching, the American Association for the Advancement of Science, as well as foundations that support their work – the National Science Foundation, for example, and the Carnegie Corporation of New York – have been organizing, meeting, and collaborating to align policies and practices within and across states, provide materials, and support coordination of efforts.

Science Teacher Professional Development

A crucial component of instructional reform has been a focus on human capital, which has focused both on the educator workforce and on programs to contribute to professional learning. While "professional development" is often conceptualized narrowly to mean short term workshops or "PD days" offered by a school or district,[4] historically there also has been a range of informal and formal opportunities to support teacher learning. Mentor teachers work with novice teachers both in induction programs and in school-based collaborations; cooperating teachers and field instructors work with prospective teachers from teacher preparation programs that are based both in higher education and through residencies in school districts. Instructional coaches, often associated with a particular content domain (literacy, mathematics, science, for example), are hired by school districts to work across schools to build capacity. Faculty in higher education teach teacher preparation courses and advanced degree programs for practicing teachers. School improvement committees or professional learning communities in schools are led by teacher leaders or school principals; summer institutes, special programs funded by the National Science Foundation, the National Council for the Humanities, or special federal, state, or local programs are also available. Teachers pursue certification through organizations like the National Board for Professional Teaching Standards. Professional organizations also offer professional development workshops, textbook and testing companies send out representatives to help teachers learn about new curricular materials. As the educational marketplace has diversified, an increasing number of vendors have appeared, offering assistance to schools and districts in coordinating their reforms, including professional learning opportunities for classroom teachers and their principals. Some teachers avidly and actively pursue learning opportunities across this spectrum; others engage in the PD required or offered by their schools.

Research on Professional Development

Since the turn of the 21st century, there has been an explosion of interest in teacher professional development, as well as investments in both development and research. Research syntheses have attempted to summarize the major patterns of findings within and across domains like mathematics and science teacher professional development, or K-12 teachers more generally. Among the commonly cited reviewers of the literature, Desimone (2009, 2011) nominates five "core features": (1) a focus on a particular content area and on how students learn that content; (2) coherence with school, district, and state policies like teacher evaluation and student testing; (3) teachers actively engaged in their learning through small group work, observing classrooms, presenting to peers, and engaging in investigations; (4) collective participation of teachers from the same school, grade level, or subject matter; and (5) sufficient duration, lasting at least 20 hours.[5] These commonplaces resonate with research on professional development across the K-12 sector and different content areas (e.g., Borko, 2004; Gersten et al., 2010; Hill & Ball, 2004; Penuel et al., 2007; Penuel et al., 2011; Roth et al., 2011). It also resonates with research on systemic and comprehensive reform (e.g., Cohen & Hill, 2001; Cohen et al., 2013; Goertz, et al., 1995; Reiser, 2013; Rowan et al., 2009; Sykes & Wilson, 2016).

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[4] Although some authors have argued for the use of "professional learning" in lieu of professional "development," we use the terms interchangeably.

[5] Lynch et al. (2019) did not find support for duration as a critical component. In general, across syntheses of the literature not all of the core features are found to be equally supported by the empirical literature.

In a more recent synthesis, Darling-Hammond et al. (2017) propose a slightly different configuration of core features, including (1) content focus, (2) collaboration (often in job-embedded contexts), (3) active learning (including opportunities to engage in the same style of learning teachers are expected to offer their students), and (4) sufficient duration, as well as the provision of (5) coaching and expert support, (6) time for feedback and reflection (including opportunities to make changes in practice given feedback and reflection), and (7) the use of models of effective practice (including lesson and unit plans, observations of teachers, and digital recordings of teachers' practice).

As the research base has expanded, scholars have added additional nuance to our collective understanding of professional development. Summarizing additional recent research, Desimone and Garet (2015) offer a set of additions and caveats:

> (a) changing procedural classroom behavior is easier than improving content knowledge or inquiry-oriented instruction techniques; (b) teachers vary in response to the same PD; (c) PD is more successful when it is explicitly linked to classroom lessons; (d) PD research and implementation must allow for urban contexts (e.g., student and teacher mobility); and (e) leadership plays a key role in supporting and encouraging teachers to implement in the classroom the ideas and strategies they learned in the PD. (p. 254)

For the purposes of the case that follows, we summarize this current state of knowledge in nine core features of effective professional development :

- content focus (often involving examining student work)
- collaboration (often in job-embedded contexts)
- active learning (including opportunities to engage in the same kinds of experiences that teachers are expected to offer to their students),
- sufficient duration
- coaching and expert support
- time for feedback and reflection (including opportunities to make changes in practice given feedback and reflection)
- the use of models of effective practice (including lesson and unit plans, observations of teachers, and digital recordings of teachers' practice)
- supportive working conditions (including, coherence with school, district, and state policies like curriculum, teacher evaluation, and student testing and strong principal leadership)
- responsive to the challenges of urban education (including teacher and student mobility)

The roots of this list are in the best practices literature – syntheses of what scholars observed about professional development and the accumulated wisdom of practice of those who designed PD (e.g., Guskey, 1986; Loucks-Horsley et al., 1998). They then have been annealed through empirical research that has used quasi-experimental and experimental research designs to find correlative or causal relationships between these features and outcome measures like

quantifiable changes in teacher knowledge, teacher practice, or student achievement on standardized assessments. There exists disagreement about how well the research base has withstood these tests, largely because several large scale efforts have failed to find significant associations, including several large scale studies funded by IES: Arens et al. (2012) found no statistically significant effects of a curricular intervention and professional development program on the language proficiency of ELL learners. Although Garet et al. (2008) found modest positive impacts on teachers' knowledge of scientifically based reading instruction neither of the two early reading PD interventions they tested led to significantly higher student test scores at the end of the first year of the treatment. No statistically significant teacher or student outcomes were found one year later.

However, in a random clinical trial of three related professional development interventions for elementary science teachers, Heller et al. (2012) found that each improved teachers' and students' scores on science tests, and that the results were maintained a year later. Grigg et al. (2013) also found a positive effect in a randomized trial that investigated whether a PD initiative influenced the teaching practices of 4th and 5th grade science teachers. The researchers found that the interventions increased the incidence of selected features of inquiry-based science teaching.

Reviews of the research have also suggested conflicting conclusions. Yoon et al. (2007) found nine studies out of the 132 they reviewed that met the What Works Clearinghouse evidence standards, making it impossible to draw conclusions about the features of high quality professional development. Gersten et al. (2014) identified 643 studies of professional development interventions for K-12 teachers of mathematics. Five of the studies were determined to have meet WWC evidence standards, and only two of those found positive effects on student achievement. In her review of professional development research, Kennedy (2016) located 26 studies in English/language arts, mathematics, and science, but found that the core features of PD like content-focused, teacher collective participation, and duration did less well at predicting positive outcomes than features related to helping teachers dig into their own instructional practice or use new instructional ideas.

Hill and her colleagues (Hill et al., 2020; Lynch et al., 2019) fared even better, locating 95 studies that used quasi-experimental or experimental designs to study the effects of STEM professional development on teacher and student learning. The average PD program had a significant effect on student learning; however, the two hallmarks of those programs were a focus on helping teachers learn to use curriculum materials and on improving teachers' knowledge which are related to the touchstones identified in studies of effective PD, but not themselves explicitly named features. The researchers found no positive or negative associations with activities that are often enumerated in the core features lists, including reviewing student work or solving content-related problems, or significant effects of kit-based science PD. Meanwhile, researchers on other projects continue to find positive statistically significant results supporting the core features of PD (e.g., Roth et al., 2019), as well as the power of activities like coaching (Kraft et al., 2018) to shape teacher instruction in ways that leads to improve student outcomes.

However, efforts to identify core design features have been repeatedly criticized, noting that such lists are based on a process-product logic (Opfer & Pedder, 2011); shift attention away from relevant theoretical frameworks (Sztajn et al., 2011); fail to highlight the fact that

researchers use "different conceptions of teaching [and] different conceptions of how PD can improve teaching" (Kennedy, 2016); and fail to differentiate between different theories of action that underlie various PD programs (Kennedy, 2016). In their review of extant research on science teacher learning, the authors of the NASEM (2015) report note additional weaknesses:

> Few studies have systematically examined each feature to identify variations within and among features and how these variation connect to teacher learning, fewer still have looked at the impact of programs on teaching practice, and even fewer have examined impacts on student learning (Desimone, 2009; National Research Council, 2011). However, recent research has begun to explore these connections (e.g., Heller et al., 2012; Roth et al., 2011). When the elements of the consensus model have been studied using designs that allow for testing of each feature, the results have not consistently supported the model (Garet et al., 2008; Garet et al., 2011; Scher & O'Reilly, 2009), suggesting that these features may capture surface characteristics and not the mechanisms that account for teacher learning. (p. 118)

Research on the Professional Knowledge and Practices of Professional Development Leaders

Every teacher learning opportunity is orchestrated and offered by personnel. Summer institutes focused on content have often involved teams of disciplinary scholars (e.g., mathematicians or scientists) and experienced teachers. Some programs follow a teacher-of-teachers model, where a smaller cadre of teachers attend a workshop and are then anointed to lead similar workshops for their colleagues in their school or district. Other teacher-led learning opportunities include teacher book clubs and study groups. Teacher educators have positions in universities, either in schools of education or relevant disciplinary departments. Experienced teachers apply to be coaches, mentors, supervising or cooperating teachers, and instructional leaders in central office positions or for special projects. Non-profit organizations hire staff to lead professional development. Projects funded to conduct research and development with Institute for Education Sciences, the National Science Foundation (NSF), and private foundation funding also regularly have curriculum and program developers to design and lead professional development in implementation studies. An increasing number of new actors, like Leading Educators, Teaching Lab, and Instruction Partners, offer their services to school districts interested in partnering with them to provide teachers with professional development which is intended to raise student achievement. Alternatively called facilitators, teacher leaders, teacher developers, professional development leaders, teacher educators, coaches, mentors, and the like, this subset of the teacher workforce is essential to teacher development and school improvement, but seldom the focus of research. Moreover, we know little about what special knowledge and skills make them effective. More often than not, there is little systematic advanced preparation for them to take on these roles. As with teachers, it has often been assumed that they need little formal or specialized professional preparation beyond their own teaching experience and becoming familiar with the relevant PD or training materials.

One challenge with examining the existing research on the education of teacher developers is that the role is diversified, the research that does exist is ensiloed. There is scholarship and other literatures, for example, on the selection, preparation, and practices of mentor teachers and coaches, both within the U.S. and globally (e.g., Achinstein & Athanases,

2006; Beutel & Spooner-Lane, 2009; Fairbanks et al., 2000; Little & Nelson, 1990), just as there is scholarship on the teacher educator workforce and their preparation and experience (e.g., Goodwin et al., 2014). There are books and manuals on the preparation of professional development leaders, for example, the online facilitator guides (https://www.nctm.org/dmi/) that accompany the *Developing Mathematical Ideas* materials, and accompanying video materials and casebook (Schifter et al., 2012), or Carroll and Mumme's (2007), *Learning to Lead Mathematics Professional Development*, which includes both a handbook and two DVDs of video cases, annotated agendas, facilitation notes, PowerPoint slides, and participant handouts. The literature is a mix of what one might call the wisdom of practice, best practices, self-study, normative arguments or logical analyses, and social science research drawing on a wide array of disciplinary and methodological traditions. Because very little funding has been dedicated to such research, the majority of the research is modest in scale, often conducted by the professional development project staff about their own programs.

In NGSX, the leaders of professional development are referred to as facilitators, as NGSX positions them not as experts offering colleagues their knowledge but rather colleagues who are skilled in helping teachers leverage their own knowledge and skill, while also constructing new knowledge and skill along the way. While it may seem obvious to some, the belief that human beings (in this case, teachers) can improve themselves is not universally shared, but is nonetheless a hallmark of the helping professions, including teaching, psychotherapy, and nursing (Cohen, 1989). From this perspective, professional development does not entail experts "fixing" teachers, but rather involves skilled leaders enabling teachers to engage in self-improvement.[6] The goal of professional development is, then, to enhance and release educators' capacity to reform their own practice over time. Moreover, because facilitators are peers, their credibility is rooted, in part, in their own efforts at continual self-improvement. We return to the role of the NGSX facilitators in the case we present below.

There is a modest literature that examines the knowledge, skills, practices, and preparation of the leaders of such professional development, primarily in mathematics and science. The existing scholarship falls into two clusters: (1) theoretical mapping of and empirical inquiries into the professional knowledge and practices required for quality facilitation and (2) research on the preparation of professional development leaders. We discuss each briefly.

Mapping the Professional Knowledge of Facilitators. Paralleling past efforts to conceptualize the professional knowledge base of teaching (e.g., Hiebert et al., 2002; National Board for Professional Teaching Standards, 2016; Shulman, 1987), some science and mathematics educators have proposed components of the knowledge base necessary to facilitate professional development. For example, based on their extensive experience offering professional development for seminar leaders and their analysis of several representative cases of challenges faced by facilitators, Schifter and Lester (2002) proposed that facilitators should have substantial content knowledge, knowledge of the goals of the professional development, and knowledge of the teachers participating in the PD, including teachers' relevant knowledge and beliefs. Similarly, Borko et al. (2014), reasoning analogically from the idea of mathematical knowledge

[6] Throughout the paper we will use facilitators, teacher leaders, and professional development leaders interchangeably. For NGSX, we will use the terms facilitators-in-training and participants interchangeably as well.

for teaching (Ball et al., 2008), proposed that there might be a mathematical knowledge for professional development, which would include substantial content knowledge, pedagogical content knowledge of engaging teachers-as-learners, and knowledge of how to create and maintain teacher learning communities. Facilitator pedagogical content knowledge includes the ability to engage teachers in purposeful activities and conversations about those mathematical concepts and relationships intended to be covered during the PD.

Increasingly, there has also been an interest in conceptualizing the *practices* of leaders of professional development, in the same spirit that teacher educators have enumerated the core practices of teachers (e.g., Ball & Forzani, 2009; Grossman, 2018; Lampert, 2010; Lampert et al., 2013; Stroupe et al., 2020; Windschitl et al., 2012, 2019). For example, Borko and her colleagues (2011) proposed that leaders of mathematics PD need to master three facilitation practices: engaging teachers in productive mathematical work; (2) leading discussions about student reasoning and instructional practices; and (3) building a professional learning community (Jacobs, et al., 2017). The researchers also found that facilitators need to identify mathematically worthwhile tasks that are relevant to teachers. Scholars interested in the use of video in teacher professional development have focused on facilitation practices, for example, that involve posing productive questions to engage teachers in discussing video, making and maintaining connections between the content (e.g., mathematics) and the video, or inviting widespread participation in discussion in ways that encourage the voicing of multiple perspectives (e.g., van Es, 2010; Van Es & Sherin, 2002, 2006, 2007; van Es et al., 2014; van Es et al., 2015; Zhang et al., 2011).

Primarily, the scholarship that maps professional development leader knowledge and practices uses logic to propose dimensions of knowledge and practice or small scale studies that are based on professional development programs that the researchers themselves designed. As with traditional job analyses and, more recently, standard setting (e.g., National Board for Professional Teaching Standards, state standards for teachers, INTASC standards), designers and developers of professional development identify the core aspects of the work of leading professional development and then make logical or normative claims to the kinds of knowledge or practice required to successfully engage in that work or empirical claims based on their experience designing and implementing PD for facilitators. Underlying these efforts is the assumption that leaders of professional development need to have a more extensive knowledge base about teaching, learning, teacher learning, schools, students, context, and content than do the teachers with whom they work. Most projects focus on a subset of facilitation skills and knowledge that are especially relevant to professional development program in question.

Research on the Preparation and Practices of Professional Development Leaders

As Lesseig et al. (2017) note, "we lack research-based principles to guide the design of leader preparation" (p. 592). Recently, a modest literature has emerged, that either describes programs designed to prepare facilitators or examines supports that can help leaders prepare to lead professional development, including co-planning and rehearsing (Benedict-Chambers, 2016; Borko et al., 2014; Even, 2005; Horn & Little, 2010; Lampert, 2010; Lampert et al., 2013; Remillard & Geist, 2002; Santagata, 2009; Zaslavsky & Leikin, 2004). Much of this limited research derives from programs of mathematics-focused video-based PD, which Jacobs et al. (2017) term "adaptive" PD, described as:

> PD programs vary according to their focus, duration, goals, and resources, among other things. Previously, we have argued that PD programs can be understood as falling on a continuum from highly adaptive to highly specified (Borko et al., 2011a; Koellner and Jacobs 2015). . . . Highly adaptive programs are designed to be readily responsive or adapted to the local context. Facilitators are likely to have a relatively strong voice in setting the broad components of adaptive PD, including determining the activities that teachers will engage in and defining the structure of their engagement. By contrast, highly specified programs are intended to support a particular learning environment with predetermined goals, activities, and resources. Facilitators of highly specified PD programs are less likely to select activities; rather, they must become familiar with the tasks and structures provided by the PD. (p. 2 of 14)

For example, Borko et al. (2017) report on their on-going work using the Teacher Leadership Preparation (TLP) model. Using a design-based implementation research (DBIR) approach, researchers in a research- practice partnership between Stanford University and the Urban Unified School District (UUSD) worked on the development of two models: the Problem Solving Cycle (PSC) model of professional development in which teachers engage collaboratively in working on math tasks and discuss videos of mathematics classrooms and the Mathematics Leader Preparation (MLP) model for PD leader preparation, which was initially designed to prepare facilitators to lead Problem Solving Cycle workshops. The researchers were interested in the questions: "What adaptations needed to be made to the models?" and "What district conditions shaped those adaptations?"

As a launching pad, the project used the work of Smith, Stein, and their colleagues on five practices for orchestrating productive mathematics discussions (Stein et al., 2008, Smith & Stein, 2011): (1) anticipating student responses, (2) monitoring student work, (3) selecting students to present their work during discussions, (4) sequencing student responses, and (5) connecting student responses. Based on those practices, Borko, Jacobs, and colleagues (2014) identified six elements associated with planning and orchestrating video-based discussions that facilitators would need to master: (1) determining the goals for the discussion and selecting video clips, (2) identifying features of the video clip that are important for meeting the goals, (3) crafting questions to guide the discussion, (4) eliciting teacher thinking about the lesson segment, (5) probing for evidence, and (6) helping the group to connect their analyses to mathematical and pedagogical ideas (Borko et al., 2014). During the leadership institute, participants were given multiple opportunities to rehearse these skills while planning and leading a discussion. Teacher leaders expressed discomfort with rehearsing facilitation and so the researcher-developers added more support and scaffolds, including an opportunity to walk through a rehearsal before genuinely rehearsing in front of others. They also instituted the use of the Praise-Question-Polish protocol which is a strategy for peer feedback designed to guide participants through the process of providing constructive feedback to peers. Participants were also encouraged to sometimes take on the role of a teacher and sometimes as a teacher leader.

In another study, Jacobs et al. (2017) reported on an efficacy study of Learning and Teaching Geometry, a video-based mathematics professional development program (LTGPD) that involves 54 hours of professional learning for secondary school mathematics teachers and is aligned with the Common Core State Standards for Mathematics. The professional development

program has been shown to lead to significant increases in teachers' content knowledge and pedagogical content knowledge, as well as significant increases in their students' content knowledge. Also using a design research approach, the research team created a video-based professional development program for future LTGPD facilitators. Facilitators-in-training were provided with detailed agendas for each workshop session (including PowerPoint slides, video clips and transcripts, mathematical tasks, and an array of other handouts). Also provided is a facilitator's guide, interactive computer applets, and embedded assessments. An LTG Efficacy Study explored whether the PD could be enacted with integrity across multiple settings with facilitators who had not been intimately involved in the program's design.

One facilitator, Hannah, was selected as the test facilitator. After studying the materials, seeking advice from the co-PIs, attending to the specifics of each session agenda, and participating in a two and a half day facilitation rehearsal, Hannah's facilitation was documented and assessed using two fidelity instruments. The researchers found that Hannah had timing adjustments in every session she facilitated, evenly split between extending and shortening time; the researchers judged that these adjustments had no impact on PD quality or content. Hannah also made content-focused adaptations in an effort to meet the participants' mathematical learning needs. Raters judged these adaptations to be productive and in line with the PD's goals. In general, the researchers found that facilitators could be prepared to offer professional development in ways that allowed them to adapt to local circumstances without compromising the integrity of the PD. They were especially aware of the importance of rehearsals:

> Rehearsals ensure that novice facilitators are able to practice using the PD materials in a structured environment, experiment with facilitation moves, and gain confidence in their role as a leader of a given PD program. In addition, rehearsals enable the measurement of fidelity and provide information about whether a facilitator is ready to implement the PD or whether additional training and support is needed. Finally, rehearsals provide an opportunity for facilitators to receive valuable feedback, in particular on the nature and impact of their adaptations, which can lead to more reflective and skilled practice. (p. 12 of 14)

In sum, research on the developing of PD facilitators has involved analyses of needed knowledge and skill and/or small scale studies, several of which used a DBIR approach to the research and self-study. These studies have focused primarily on the connections between facilitator learning opportunities → subsequent changes in facilitator knowledge, skills, and facilitation moves → teacher learning opportunities. The existing research has not provided thick descriptions of how the teachers' ideas (and perhaps practices) were changing, nor of teachers' perceptions of their learning experiences.

The study we report on here builds on what is known about professional development, while also providing a novel view into PD experiences from the perspectives of facilitators-in-training. Through participants' comments while learning to facilitate, we aim to shine light on participants' perceptions of how they experienced specific aspects of the NSGX PD, and what sense they made of it.

Research Design and Methods

The purpose of this study is to describe and explain the experiences of professional development facilitators participating in the Next Generation of Science Exemplar Facilitator Pathway (NGSX). The research design is a case study of one professional development program which was offered at more than 50 sites across multiple states. Stake (1995) defines case study as "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (p. xi). Case studies have multiple purposes, among them to "describe and explain" a phenomenon (Rowley, 2002). Case studies are particularly appropriate when "a how or why question is being asked about a contemporary set of events over which the investigator has little or no control" (Yin, 1994, p. 9).

Shulman (1986) posits that, because different research programs produce different types of knowledge, research on teaching might encompass knowledge that takes the form of empirical propositions, moral propositions, conceptual inventions, exemplars of practice or malpractice (cases), or technologies/ procedural protocol. Shulman does not propose that these forms of knowledge are developmentally related, that is, that empirical propositions are produced in the later stages of a research program, but rather that they play complementary roles in the composition a field's knowledge base. We believe that research on teacher development would benefit from thick cases of teachers' experiences within a PD program to complement the empirical propositions that currently dominate the discourse on describing effective professional development.

It is essential with case studies that one defines the boundaries of the case (Merriam, 1998). A bounded context can be a person, an organization, a class, a policy, or any given unit of study. Here the case is NGSX as it was experienced by two cohorts of participating facilitators-in-training from 2015 and 2017 in two states. In other analyses, we conduct cross-state comparisons. Here our goal is to explore common themes in facilitators-in-training reflections across the two sites. Our goal is a holistic interpretation of facilitator learning in a natural setting. As Merriam (1985) explains:

> The case study results in an intensive, holistic description and analysis of the phenomenon or social unit being studied. It is characterized by what Geertz (in Guba and Lincoln, 1981) calls "thick description."
>
> > Thick description involves literal description of the entity being evaluated, the circumstances under which it is used, the characteristics of the people involved in it, the nature of the community in which it is located, and the like... Thick description also involves interpreting the meaning of such demographic and descriptive data in terms of cultural norms and mores, community values, deep-seated attitudes and motives, and the like. (p. 1la)

Rather than surveying a few variables across many cases, the case study intensively examines the interplay of all variables in order to provide as complete an understanding of the phenomenon as possible. Several methods of collecting data are used to reveal the total picture of the case under study (Merriam, 1985).

Data Sources

The analysis presented here relies primarily on reflections written by facilitators-in-training during their participation in the professional development and recorded on the web-based platform. Reflections were standard fare in the professional development, and consisted of participants regularly writing comments (usually online, but sometimes posted as pdfs to the digital platform), ranging from one sentence to several paragraphs; some reflections were written by small groups who had deliberated on a particular prompt, other reflections were posted by individuals. During the reflection periods in a particular cohort, participants could see one another's responses, and often one respondent would refer to comments made by others.

Two other data sources also informed the inquiry: observations of professional development sessions (which included informally speaking with participants) and ethnographic visits to the schools of participating teacher leaders (which included unstructured ethnographic interviews). In total, the first author or a research assistant observed 20 professional development days in two states (five in Michigan; 15 in Connecticut), taking handwritten field notes throughout and collecting all associated documentation. Wilson also visited eight facilitators and the teachers who they worked with in Connecticut schools, taking ethnographic field notes of classroom and school observations, as well as conversations with the teacher leaders. No data were digitally recorded during field visits, and after each observation and school visit, Wilson found a quiet place (often in her car) to immediately go back to her field notes and fill in any gaps. The asymmetry in data collection was driven by the proximity of the researcher to the sites.

Other data sources informed the research as well. Documents were collected (handouts from meetings, articles written by the NGSX leaders, scholarship that was referenced during conversations with the teacher participants and/or leaders, photographs of school exhibits or classroom artifacts generated by the teacher leaders in their schools, etc.), and all of the materials that were distributed to participants as part of the professional development. Additionally, the first author periodically had conference calls with the two NGSX leaders who were coordinating the work in the two states in question, during which she played the role of a critical colleague (Lord, 1994), offering observations from what she had observed or read, reacting to particular questions of the project leaders, and the like. She also sat in on several staff planning and debriefing meetings, as well as a "problems of practice" retreat that was convened to support the facilitators-in-training after they had launched their first study groups. The second author is one of the NGSX's most experienced facilitators and served as an insider informant in the tradition of Doc in Whyte's (1943) *Street Corner Society* or Hakim Hasan in Duneier's (2000) *Sidewalk*. He explained program details, helped the first author access available data, and discussed his own experiences as what NGSX staff affectionately referred to as an "uber facilitator," one of the NGSX facilitators who had more experience in the role and played a critical role in bringing new facilitators into the NGSX guild. He also had access to all of his planning materials for the professional development sessions he ran and collaborated on throughout his involvement in NGSX, as well as considerable experience supporting facilitators-in-training when they moved from the PD to co-leading study groups of teachers.

We collected data on four cohorts of facilitators-in-training in each state, as well as reading the entries of teacher-participants in several of the study groups that those facilitators later led as backdrop to our analysis (see Table 1). In other words, we immersed ourselves in

records available through the web-based platform, but we focused this analysis exclusively on understanding what facilitators-in-training reported to be learning.

Cohort	Dates	Facilitators who completed PD	Available postings to read
MI 1	9/21/15-1/09/16	17	255
MI 2	9/21/15-1/09/16	29	375
MI 3	9/21/15-1/09/16	17	255
MI 4	4/20/16-8/12/16	31	440
CT 1	6/5/15-9/19/15	24	480
CT 2	2/29/16-9/30/16	12	255
CT 3	6/20/16-10/7/16	20	378
CT 4	5/25/17-6/02/17	21	433
Total		171	2871

Table 1. *Facilitator Cohorts in Michigan and Connecticut*

Pseudonyms were used through field notes for participants, schools, locations, and districts. No identifying information was kept. In Michigan, NGSX participants in the facilitator training were primarily experienced professional development leaders who were employed by school districts and intermediate school districts to support mathematics and science teacher learning. They were recruited and selected by the Director of Michigan's Math-Science Leadership Network -- in collaboration with all of the Math Science Center directors. As we reviewed the available materials, it appeared that the MI cadres did not post on the web-based platform as often. In theory, there were approximately 30 times that a person or small group could post (for each of the 5 chapters, there were between 5-7 steps, and for almost every step there is an opportunity to post). Postings ran from one sentence to several paragraphs. Small groups, at times, posted graphics as well, although we did not use those in this analysis.

In Connecticut, there was no existing formal professional development leader network, but there had been recent efforts to build the state's capacity to offer STEM instructional coaching and professional development through federal Mathematics and Science Partnership grants the state received from 2006 on. Across the state, several coaching academies for elementary and middle school mathematics and science teachers were offered between the years of 2006-2013 (e.g., Lomask, 2013; Mutch-Jones et al., 2009). NGSX facilitators-in-training were primarily K-12 classroom teachers and curriculum leaders who had background and/or interest in science education. They were selected through a competitive process; a request for applications was sent out through state channels explaining the requirements and benefits, and asking for responses to several open-ended prompts. The state science coordinator, who had a network of connections across the state, including with previous MSP-funded efforts was central in recruiting applicants. Facilitators-in-training were paid $2700 to attend the facilitator training.

Data Analysis

> Qualitative analysis transforms data into findings. No formula exists for that transformation. Guidance, yes. But no recipe. Direction can and will be offered, but the final destination remains unique for each inquirer, known only when—and if—arrived at. (Patton, 2002, p. 432)

In interpretive research traditions, data analysis is iterative and reflexive, beginning at early stages of data collection. Throughout the research, the first author kept electronic and written journals of impressions, notes, as well as conversations with insiders (program staff) and the second author. These journals were informed by the tradition of commonplace books, and take the form of scrapbooks of notes, pasted-in snippets of articles, diagrams of settings, photos from events, and links to articles, websites, and the widest imaginable array of related texts (Darnton, 2000). Locke, Emerson, and Thoreau all kept commonplace books, as did Mark Twain, Thomas Jefferson, and Virginia Woolf. Major sources of inspiration for these notes were thoughts before and after conversations with the project leaders, conferences at which the author observed the project leaders present talks and answer questions, readings of scholarship on professional development and teacher learning, meetings of various professional organizations of which the first author was a member (the NASEM's Board of Science Education, for example), and biweekly meetings with the second author. Because the first author's broader research agenda concerns teaching and teachers, her notes on NGSX were part of the notebooks she kept from 2015-2020, the years of data collection, analysis, and writing. They exist as both iPad notes and paper journals. These notebooks represented an important form of data reduction and resource for analysis.

Qualitative data analysis is also inductive, and the researcher is constantly in search of categories, patterns, and relationships. This research was driven by an emic focus, and the researchers' goal was to represent the experiences and the setting in the participants' terms. At every turn, the goal was to keep a holistic view of teachers' learning; rather than breaking the whole into parts, the goal was to understand the stream of experience facilitators-in-training perceived, including any interrelationships among ideas that were important to them. Although the purpose was to focus on participants' meaning, we also recognize that the prompts in the web-based platform often asked participants to respond to a particular idea or aspect of NGSX. In this sense, participants' reflections might be understood as (partially) deductive, that is, they were driven by prompts concerning the foundational premises of the professional development. However, we did not use the NGSX core principles to code the data. Rather, we identified major themes that the participants returned to in their comments, selected representative quotes, and wrote memos about the nature of the emerging themes.

The redacted data for this project filled 15 reusable grocery bags, which the first author dragged between various writing retreats during data analysis (and locked in appropriate rooms). Periodically, often in preparation for discussing the project with the NGSX leaders, the first author would formulate alternative analytic schemes to test out in conversation. This produced a series of analytic memos. Memos are an essential tool in qualitative research: they keep the researcher writing, they act as a paper trail of the researcher's evolving interpretation of the data over time, and they enhance the researcher's reflexivity by serving as a mirror of one's thinking. Memos also provide an intellectual playground for the researcher to tentatively try out ideas and

take risks; they also help the researcher generate new questions to follow up on and explore (e.g., Birks et al. 2008; Charmaz, 2006; Glaser, 1978; Richards, 2005; Saldana, 2015; Strauss & Corbin, 1998). The first author also wrote analytic memos about major "chunks" of the emergent narrative: NGSS and the history of science education reform, the content and character of NGSX, the major theoretical ideas that animate NGSX, and – primarily -- the major refrains that participants persistently returned to in their reflections (in interviews, observations, and web-based) on their NGSX experiences.

Once the final set of descriptive categories to be used to structure the story were determined, the first author read through each and summarized or excerpted relevant quotes from field notes and reflections posted during the professional development before returning the page to its grocery bag. Janet Malcolm (1993) once described this stage of data analysis as the task "of housecleaning (of narrating) . . . There is a danger of throwing the wrong things out and keeping the wrong things in" (pp. 204-205). Each theme took the form of an analytic memo, which was elaborated through the search for confirming or disconfirming evidence in the teachers' postings and the authors' field notes. T.S. Eliot (1932) describes the "frightful toil . . .the labour of sifting, combining, constructing, expunging, correcting, testing" (p. 18), which involved putting the separate analytic memos into various arrangements in constructing the narrative. As a coherent narrative emerged, each analytic memo was transformed: pieces were pasted into the argument, others were deleted, still others were edited down to make the prose accessible, persuasive, and accurate. At later stages of writing, the second author, and the two NGSX project leaders read the narrative for accuracy, persuasiveness, and accessibility.[7]

The analytic memos were also used to help the authors exercise reflexivity, a hallmark of qualitative research which entails demonstrating one's commitment to attending systematically to the context of knowledge construction, especially to the effect of the researcher and the methods, at every step of the research process e.g., Chaudry, 2000; Delgado-Gaitan, 2003; Hesse-Biber & Paitelli, 2007). As Malterud (2001) notes: "A researcher's background and position will affect what they choose to investigate, the angle of investigation, the methods judged most adequate for this purpose, the findings considered most appropriate, and the framing and communication of conclusions" (pp. 483-484). Reflexivity involves introspection, self-consciousness and self-awareness, and a commitment to interrogating one's choices, interpretations, and assumptions, as well as making those transparent to readers. In this study, we exercised reflexivity through the use of three major forms of data (participants' written reflections, professional development observations, and ethnographic interviews with participants after site visits); through periodic conference calls with project leaders to offer observations and test out potential analyses; member checking, first with the second author (who himself is a facilitator) and then with the project leaders; analytic memos; the construction of commonplace books, and thick description.

[7] The first author's decision to not use a digital coding platform to support the analysis was driven by concerns for the inherent conflict of reducing analysis to computerized algorithms with the epistemological and ontological assumptions underlying this interpretivist study. The use of analytic memos allowed for preserving data in a more holistic form.

The Case:
Next Generation of Science Exemplar (NGSX):
A Case of Professional Development Leader Development

All professional development is anchored to implicit or explicit assumptions about what students need to learn in school and what teachers need to know and be able to do to enable that learning. The Next Generation of Science Exemplar Project (NGSX) is a professional learning system that has evolved over time to support teachers, principals, and teacher leaders in learning about NGSS and becoming prepared to use, adapt, and develop materials to support teaching to the vision of teaching and learning embodied in the *Framework* and the *NGSS*. A hallmark of these documents is 3-dimensional (3-D) learning, which includes an equal emphasis on scientific ideas, cross-cutting concepts, and practices. Although there is no singular "right" way to teach to these ends, instruction encourages students' active engagement and reasoning. In particular, 3-D learning activities "should allow students to actively engage with the practices and apply the crosscutting concepts to deepen their understanding of core ideas across science disciplines" (https://www.nextgenscience.org/glossary/three-dimensional-learning).

Beginning in 2013, the NGSX creators -- Sarah Michaels, Jean Moon, and Brian Reiser -- collaborated in designing and developing the initial pilot NGSX learning pathway. They explain their approach as follows:

> NGSX is a blended model of professional learning, combining face-to-face work in a study group and a high functioning web platform that supports the NGSX pathways website. Generally, a study group is between 20 and 25 participants, who with the help of a skilled facilitator engage as a learning community. Study groups participate in and analyze three-dimensional (3D) science learning – learning that draws on NGSS and the National Academies' *Framework for K-12 Science Educatio*n. (https://www.ngsx.org/aboutus)

NGSX, as a system, does not presume that all educators or policymakers understand scientific core ideas or cross-cutting concepts in equally complex ways, nor does it presume that all educators have experience with and understand the range of scientific practices. However, NGSX does not position itself as a set of experts disseminating information to teachers in the classic Research, Development, Dissemination, and Utilization (RDDU) model[8], but rather views teachers as professionals who are the primary agents of their own improvement. Thus, NGSX does not primarily see itself as delivering instructional ideas and materials to participants, but rather enriching and unleashing teachers' abilities to help create, test, and refine the knowledge, skill, and materials necessary to fundamentally reform U.S. science education.

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[8] In the 1960s, the federal government began to build research and development infrastructure that was intended to link the production of knowledge to educational practice through the establishment of a network of institutions to carry out activities characterized as a chain linking research to development to dissemination and use the Research, Development, Dissemination, and Utilization (RDDU) model. Educational laboratories were established, as were university-based research centers and technical assistance agencies of various kinds. This federally-sponsored system of institutions also had counterparts in many states where Intermediate School Districts (ISDs) or Boards of Cooperating Educational Services (BOCES) provide assistance to schools and districts oriented at least loosely around research or research-based ideas of "best practices" (Sykes & Wilson, 2016).

Underlying Theoretical Ideas

A broad set of conceptual ideas inform the NGSX approach to educator development. The NGSX designers understand instructional reform from a historical, organizational, systemic, and sociocultural perspective. As an interdisciplinary team, they possessed complementary expertise in the learning sciences, classroom discourse, science education reform, educational policy, professional development, curriculum research and development, and collaborating with teachers, researchers, policymakers, and other stakeholders in the educational system. Each is a boundary crosser, who travel regularly between the worlds of K-12 practice, teacher development, research, and policy.

While the project focused heavily on educator development and investing in both human and social capital, the emergent theory of change included an approach to soliciting/negotiating state, school district, and school buy-in. In addition, as the project evolved the development of K-12 curriculum resources became another essential element of comprehensive and systemic approaches to instructional reform (e.g., Cohen, 1995; Cohen et al., 2013; Smith & O'Day, 2008; Sykes & Wilson, 2016). Thus, the project situates educator learning within the educational system and schools. The designers understand PD to be fundamentally shaped by and related to other policy levers, including the state and local curriculum standards, testing and assessment practices, teacher assignment and evaluation, school and district culture and policies, as well as by students, their families/caretakers, and broader communities. Central to this conceptualization is a commitment to attending to relationships over time; professional development is not something that is packaged, delivered, and then sunseted. Rather, it is planted, nurtured, and cultivated. While the NGSX staff may eventually leave, there is an assumption that what they have co-constructed with the participating will remain.

Here we focus on the set of theoretical ideas that animated the developers' understanding of educator learning. The project's overarching frame is sociocultural and adheres to the idea that learning occurs in the social interactions of individuals and groups, and that language, social norms, and social structures shape the development of knowledge and cognitive abilities. This perspective is juxtaposed with what Kelly (2006) calls a cognitivist perspective, which aligns with the popular RDDU model, that presumes that experts – in this case, teachers and teacher development leaders – acquire knowledge and skill in one setting and then use it elsewhere. That perspective does not readily allow for the possibility that knowledge and skill may be distributed among group members. Kelly (2006) argues that a sociocultural understanding of teacher learning would presume that

- Teacher expertise is distributed
- Teachers have knowledge-in and knowledge-of-practice (Schon, 1983, 1987)
- Teacher expertise is situated (Lave & Wenger, 1991)
- Teacher learning involves moving from peripheral to full participation (Lave & Wenger, 1991)
- Teacher identity matters

From this perspective, professional learning is understood as knowledge building, and is often best done through collaborative problem solving and dialogue while working on authentic

problems using social practices. Teacher reflection is essential to the on-going development of that knowledge:

> The pathway to expertise is through engagement in practices, moving toward full participation in tasks of increasing accountability; expertise is reciprocally and interpretatively constructed through engagement. Over time, participants acquire the facility to engage successfully in the discourse, norms, and practices of a particular social practice. (Kelly, p. 511)

Based on these ideas, the NGSX designers describe classrooms as knowledge building communities, in which teachers and students engage in 3-dimensional learning experiences (Reiser et al., 2017). From its inception, NGSX envisioned teaching as collaborative work between teachers and students. The concepts of knowledge building and knowledge building communities are rooted in the work of Bereiter and Scardamalia (Bereiter & Scardamalia, 2014; Scardamalia, 2002; Scardamalia & Bereiter, 2003), who proposed that learning involves building knowledge and that the knowledge construction process entailed authentic problems, improvable and diverse ideas, epistemic agency (students are active participants in the entire process), collective responsibility, the construction of knowledge through discourse, the constructive use of authoritative sources, and the democratization of knowledge, among others. This requires reimagining what students do in classrooms, with an emphasis on building knowledge through intentional activities instead of enacting classroom rituals while quietly obeying rules designed to keep order:

> Seeing science as a set of practices shows that theory development, reasoning, and testing are components of a larger ensemble of activities that includes networks of participation and institutions . . . specialized ways of talking and writing . . . . the development of models to represent systems or phenomena . . . . the making of predictive inferences, construction of appropriate instrumentation, and testing of hypotheses by experiment or observation. (NRC, 2011, p. 43)

From this perspective – and aligned with Bereiter and Scardamalia's knowledge building -- students are positioned as "*epistemic agents*, individuals or groups who take, or are granted, responsibility for shaping the knowledge and practice of a community (Stroupe, 2014, p. 488). Further, teacher and facilitator professional development opportunities ought to be conceptualized similarly as taking place in knowledge building communities in which participants co-construct "new understandings with colleagues and work[ing] together to understand, apply, and reflect on the reforms put forward in the National Research Council's Framework and NGSS" (NGSX Facilitator Pathway, p. 1). In those knowledge building communities, teachers and facilitators develop their ideas, take intellectual and pedagogical risks, experiment with new curriculum and instructional tools, discuss and debate what they are learning, and eventually produce new knowledge of teaching science that can inform broader communities of educators. Acknowledging teachers as professionals who are central in creating the curricular and pedagogical knowledge, practices, and materials essential to NGSS-aligned teaching and learning, NGSX teachers too are to be empowered as epistemic agents. Similarly, NGSX

facilitators are positioned as epistemic agents empowered to master and extend the craft of leading professional development.[9]

In sum, the NGSX theory of change draws on sociocultural views that align with several core features of professional development, including participant collaboration, immersion, active learning, and modelling. The sociocultural lens posits that learning takes place in a knowledge building community into which teachers are socialized, and knowledge is co-constructed by the group. These ideas also turn Lortie's (1975) apprenticeship of observation on its head: If teachers tend to teach as they have been taught, professional development needs to interrupt the traditional apprenticeship of observation by creating a new milieu in which teachers witness and learn new practices, so that they might use those with their own students.

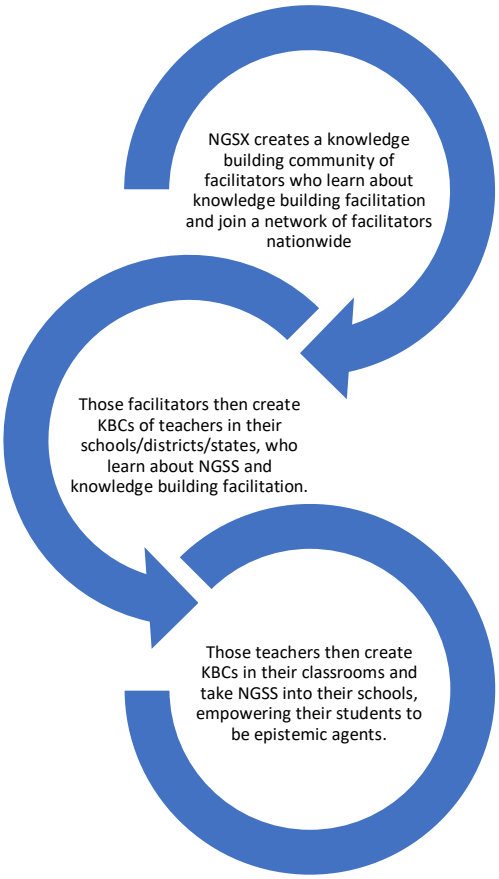

Figure 1. *NGSX Theory of Change*

[9] The emphasis on the agency of teachers and students aligns with the ascendance of this concept in the science education research literature more generally (e.g., Clarke et al., 2016; Martin, 2016; Rappa & Tang, 2017).

A critical feature of this theory of change is that, at every step, there is a feedback loop, which informs continual improvement of the PD. Feedback from facilitators about their experiences has led to changes in facilitator preparation, feedback from participating teachers and facilitators has led to changes in the PD offered to teacher participants, and feedback from teachers about implementation in their schools and classrooms has led to changes in both the facilitator preparation and PD for teachers,

NGSX Pathways[10]

The NGSX system consists of multiple "pathways" for different learners. At the time of this research, there was a pathway for teachers (the NGSX Matter Pathway), a pathway for principals and school leaders (Principals Learn About, Network, and Support 3-Dimensional Science Learning (PLANS)), and a pathway for facilitators (the NGSX Facilitator Pathway). The multiple pathways reflect the NGSX leaders' systemic, comprehensive, and ecological views of instructional reform. They did not believe that teachers can be successfully prepared to teach in ways aligned with NGSS if their facilitators, coaches, mentors, and principals are not all on the same page. NGSX leaders have also coordinated their work with state level officials in an effort to articulate NGSX with state and district policies and practices.

During the time of our study, each pathway involved face-to-face study groups. Participants went through units and steps on a pathway and used learning resources such as videos of classroom cases, reading and analyzing transcripts of those cases, engaging in doing science activities, trying out new pedagogical tools such as epistemic mapping and posting reflections that brought to the surface questions, new learnings as well as challenges. All these resources are available to participants on the NGSX web-based platform. Throughout, participants are regularly entering their reflections into the system, which could then be used by the professional development leaders to adjust plans for future sessions and to analyze PD retrospectively for program refinement. Before the advent of COVID-19, the NGSX designers had already begun working on more online professional development, and since the onset of the pandemic, most of the PD pathways are completely online.

In person, the Matter Pathway lasted approximately 36 hours, as did the Facilitator Pathway; the Matter Pathway was typically offered in full 8-hour days spread across several weeks. Participants had access to the web platform for about three to six weeks; after the active involvement of the NGSX staff ceased, participants could no longer access the platform for reasons of intellectual property. PLANS is shorter, given the multiple demands on principals' time, and lasts 11 hours, which is typically offered in 1 or 2-day sessions that are spread across two weeks. The goal of PLANS is to help instructional leaders, district personnel, and principals to learn about and identify the resources, infrastructure, and policies needed to support teachers as they implement NGSS over time.

The Facilitator Pathway, the focus of this study, was designed for facilitators who would eventually lead the teacher NGSX pathways. Facilitators may be K-12 science teachers, STEM mentors and coaches, district science leaders, professional development leaders, informal science educators, and science teacher educators. Because facilitators will be offering the Matter Pathway

[10] See Reiser et al. (2017) for a complementary description of the NGSX Matter and Facilitator Pathway.

to teachers, they also need to participate in the Matter Pathway. This has been handled in various ways across states. In theory, the idea is to interweave facilitators' experiences with the Matter Pathway (for teachers, which is comprised of six units) and the Facilitator Pathway (which at the time consisted of five chapters; see Figure 2).

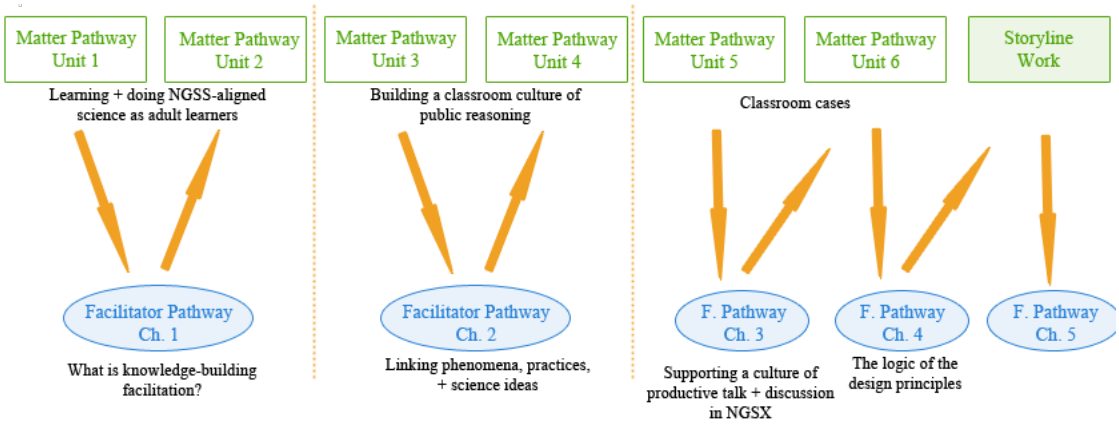

Figure 2. *Interleaving of Facilitator Pathway with Matter Pathway* (McKenna, 2016)

It is beyond the scope of this paper to flesh out the description of these pathways in extensive detail; here our goal is to offer a broad brushstrokes portrait of the Facilitator Pathway.[11] As the NGSX designers explained:

> Similar to the challenges faced by teachers (new vision, new practices) – are the challenges that professional development providers face. This kind of professional learning among adults requires a new kind of learning culture built with special attention to the role of skilled facilitators, new tools and resources including video with images of classrooms involved in the work of "figuring things out," along with multiple opportunities for participates as adult learners to work with colleagues on "figuring things" out in parallel. All of this calls for doing things that PD providers may not be doing, haven't been trained to do, and haven't experienced themselves. (Moon & Michaels, 2016, p. 1)

The Facilitator Pathway

The Facilitator Pathway currently consists of two parts. Part I is comprised of five chapters; each chapter is broken into a series of steps (see Appendix A for the full Table of Contents). During the time of this research, only Part I was available. Part II, which was developed after data collection was completed, involves helping teachers and facilitators take what they learned in the professional development into their classrooms through investigation and curriculum design. The five first chapters include:

[11] The pathways themselves have undergone revision and renumbering. See https://www.ngsx.org for up to date information. Part 2 consists of an additional two chapters: Knowledge Building to Support NGSX Participants in Units 1-3 (Chapter 6) and Putting Our Puzzle Pieces Together - Supporting Teachers as They Adapt Instructional Units (Chapter 7).

Chapter 1: What is Knowledge Building Facilitation?
Chapter 2: Tools and Critical Strategies for Knowledge Building Facilitations
Chapter 3: Supporting a Culture of Productive Talk and Discussion in NGSX
Chapter 4: A Deeper Dive into the Practice of Modeling
Chapter 5: Putting it all Together and Getting Started for Real

The NGSX designers used three "lenses" to design these materials, which Moon and Michaels (2016) called "Three Lenses on Knowledge Building Practice for NGSX Facilitators" or "the Trifecta" (see Figure 3):

- Core challenges of knowledge building facilitation (going public, listening, digging deeper, co-construction, and peer-based leadership)
- Culture-building strategies (modeling and reinforcing, recognizing different levels of experience and expertise, making explicit and public norms for productive discourse, including analyzing video; and demonstrating support and respect for the complexity of the work as adult learners
- Pedagogical content knowledge for facilitators (expert use of talk moves and positioning moves; knowing the science; knowing how to help participants analyze classroom texts; helping participants unpack the NGSS standards, including DCIs and student performance expectations; guiding participants in how to critical consume curricular material; using the NGSX story online tool to support students in building their understanding of science incrementally (NGSX Facilitator Pathway, n.d.)

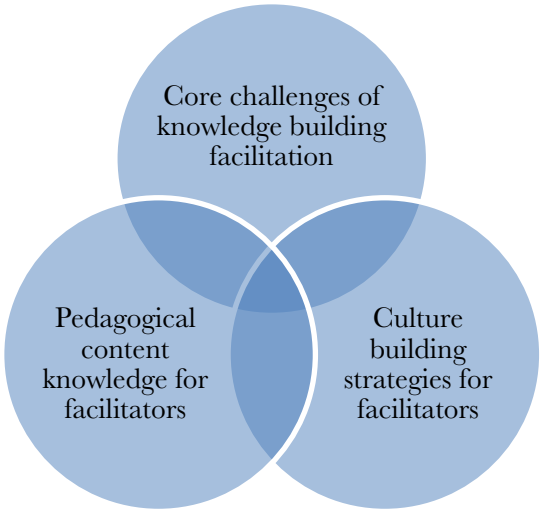

Figure 3. *The NGSX Trifecta* (Moon & Michaels, 2016)

Each chapter in the Facilitator Pathway is designed with these lenses in mind. For example, in Chapter 2, facilitators-in-training learn about facilitation strategies; Chapter 3 is designed to enhance their pedagogical content knowledge of how different kinds of discussions can support the work of collective knowledge building. Chapters are not meant to independently

address one lens, for the NGSX designers saw these three lenses are interwoven, not unlike the three dimensions of NGSS (practices, concepts, and ideas).

Throughout the Facilitator Pathway, the PD experiences that facilitators will be leading are described and laid out in detailed steps via the web-based platform, with recommended time allotments (see example in Figure 4). During the time of this study, the experiences were in person and synchronous. (The Matter Pathway is laid out in a similar way, which steps for every session, recommended time allotments, and all of the necessary materials provided through links.) Facilitators are expected to follow the steps as they are laid out, use the recommended time allotments as guides, and use the activities with fidelity. Here fidelity is not conceptualized as using the materials like a script, but instead making sure that participants experience all of the components of the professional development in ways that align with the project's theory of change and theoretical orientation (as described earlier), even as adaptations to context and participants might be called for. As Carroll et al. (2007) explain, the emphasis is more on the qualities of the program implementation and less on "dosage" or "adherence" in a strict sense of the word.

Figure 4. *Sample Excerpt from NGSX Web Platform*

Once facilitators-in-training have completed the Facilitator and Matter Pathways, facilitators-in-training are paired with one another to lead a teacher study group. They are also mentored by an "uber-facilitators," seasoned facilitators who participated in facilitator training and have been with the project for multiple years. Facilitators-in-training are also provided with additional planning materials, including agendas, lists of materials, materials needed for science investigations, and other things that support being thoroughly prepared. Facilitators were encouraged to audio- or videotape their facilitation so that they can review their work in leading a group, and solicit feedback from their mentor facilitator. In instances where facilitators were unable to record their entire facilitation, they were advised to record key discussions that they found difficult to lead. During the time of this study, these difficult sections led the NGSX developers to develop and offer an additional seminar entitled "Problems of Practice," which was based on the developers' review of parts of the Matter Pathway that were particularly challenging for novice facilitators.

Core Learning Activities. Eight major learning activities are used throughout the Facilitator Pathway. All but one of these is also used in the Matter Pathway. The major activities include:

1. Conducting science investigations, including minilectures or demonstrations on videos, as well as hands-on activities, small and large group discussions;
2. Reading documents prepared by NGSX staff, or curated research articles about science topics, instructional strategies, three-dimensional learning, and science reform;
3. Conducting case analyses of videos of classrooms and of professional development, followed by transcript analysis, and participant reflections about what they notice, in writing and in small and large group discussions;
4. Viewing videos of project staff explaining core science and education concepts and ideas;
5. Listening to think alouds/reflections by experienced facilitators about their reasoning while facilitating a discussion, in real time or after-the-fact;
6. Practicing facilitation moves and the use of various teaching tools;
7. Participating in large and small group discussions of various sorts; and
8. Writing reflections (open-ended or in response to a prompt), both individual and building on others' reflections.

The first activity – conducting a science investigation – is presented as an opportunity for the participants to put themselves in the role of a student learning science through a NGSS-like investigation. This takes place at the very beginning of the professional development, and facilitators-in-training are asked to fully immerse themselves as students and to postpone asking questions about the activities as teachers/facilitators. This is a commonplace of contemporary professional development, especially in "reform-oriented" mathematics and science professional development. The logic is that, if teachers are expected to teach in certain ways, they need opportunities to experience that teaching (recall the core features of effective professional development as well). This kind of learning opportunity is not new to PD; immersing teachers in content-learning activities was a hallmark of the Bay Area Writing Project and the California Subject Matter Projects in the 1980s (Lieberman & Wood, 2002; Wilson, 2002), as well as summer research experiences for teachers that are sponsored by industry, and through NSF grants, although not all of those PD experiences are specifically designed to immerse teachers in the student experiences.

The six other activities – reading, reflecting on experiences, analyzing video- and text-based cases of facilitation and teaching (e.g., Gaudin & Chaliès, 2015; Karsenty & Sherin, 2017; Merseth, 1991, 1996; Merseth & Casey, 1993; Miller & Zhou, 2007; Moon & Michaels, 2016; Richert, 1991; Rosaen et al., 2008; J. Shulman, 1992; Sykes & Bird, 1992), listening to uber-facilitators think aloud (Houchens et al., 2017; Pinnock et al., 2015), participating in substantively-rich discussions (Haroutunian-Gordon, 2009), watching videos of experts explaining both science and education concepts, and practicing high-leverage facilitation/discussion skills (e.g., Ball & Forzani, 2009; Grossman, 2018; Lampert & Graziani, 2009; Stroupe et al., 2020) – are used in different constellations throughout the professional development. These structures are the familiar furniture of progressive professional development that seeks to move beyond "talking head" workshops. Although less attention is paid to these canonical learning opportunities in the research on PD, they are well known by seasoned PD facilitators nationwide, and the NGSX developers were well versed in the accumulated wisdom and extant research on each.

There are several reasons for this collection of learning opportunities. For one, the professional development program is time intensive, involving long days, and multiple weeks. Breaking the time up with distinctly different activities provides needed breaks. Second, the activities appeal to different participants. Some participants voice concern about their own content knowledge, and they can be initially uncomfortable admitting some confusion during science-rich discussions. Other participants have strong pedagogical preferences – they might prefer small group discussions or lectures in which they don't have to participate. Some participants are hungry for good research-based articles to take back to their colleagues, others are more interested in activities they can use with their students. Rotating among activities increases the chances that there will be something that appeals to everyone during a day's work. The different activities also provide different perspectives on core concepts: Watching an expert facilitator may obscure how hard it is to put such a practice into place; listening to them explain their reasoning about what they were thinking about and struggling with during a discussion opens up the black box and allows novice facilitators more insight into the challenges of thinking-in-the-moment while facilitating.

Lastly, the learning activities for the teacher-participants resonate with the NGSX vision of teaching and learning, one that engages learners in authentic work in ways that activate and encourage student and teacher agency. Thus, each activity allowed for the NGSX staff to model teaching practices for participants. As one participant explains: "knowledge building must be experienced to be understood, if we want teachers to be able to do this in classrooms, they will need to have an experience of it themselves as learners" (9.22.2015).[12] "I like that training not only gives us practice in knowledge building as facilitators but as learners. We have the opportunity to experience what the participants in our groups will experience." And another: "I see how the points in the readings have been modeled in our workshop" (6.8.2016) "I keep thinking back to the way this PD is being run… I thought of the norms we use when we are having discussions" (5.23.2016). "Whenever I attend a pd of any kind, I make a list of the things

[12] Quotations are taken from participants' written reflections in the online NGSX platform, field notes of professional development observations, or field notes from visits to facilitators' schools. The date of each comment is noted when available.

the facilitator does and says to engage participants. The strategies we've learned about through reading and discussion are enacted in every part of NGSX" (11.14.2015).

Results:
Teachers' Perspectives on Learning

Here we describe facilitators' evolving ideas about the major themes of the professional development: their evolving understanding of the nature of knowledge building facilitation; their views on the pedagogical tools of knowledge building facilitation; their insights into the challenges of knowledge building facilitation; and their views on their personal preparedness for being facilitators. Not surprisingly, these themes readily map on to the designers' trifecta for NGSX foci.

Theme 1: Learning about Knowledge Building Communities and Knowledge Building Facilitation

> Knowledge Building is fundamentally a social and collaborative process. It requires the whole community to nurture a classroom culture that values wonderment, deep thinking, diverse ideas, inclusivity and equity, perseverance, honesty, and risk-taking. Knowledge Building thrives in a culture of psychological safety — a place where students feel that they can contribute their ideas and thoughts without judgment. Knowledge Building is not about getting at the right answer as quickly as possible, but about improving ideas and advancing collective knowledge on problems and questions of value to the community. (Resendes & Dobbie, n.d., p.19)

For the participants in the NGSX Facilitator Pathway, the language of "knowledge building community" might have been new, but the ideas resonated with other ideas of long-standing in education circles with which many of the participants were familiar: constructivism, student-centered instruction, and inquiry among them. The idea of professional development being designed so that teachers might belong to such a community and co-constructors of knowledge was less familiar and perhaps even antithetical to larger social and political trends in education, including heightened accountability, teacher value-added assessments, and the increasing use of teacher evaluation systems to identify low-performing teachers. This broader culture positioned teachers more as civil servants than as professionals, and was not one that engendered risk-taking or psychological safety for educators, both of which were crucial features of the teacher community that NGSX aimed to build.

From the start, most participants liked the idea of belonging to a knowledge building community of professional development facilitators. This is not surprising; the concept recognizes facilitators' experience and expertise, and positions teachers as professionals and capable of producing knowledge. But early on in their NGSX experience, many facilitators-in-training appeared to have positive but relatively unarticulated ideas about what it takes to build a knowledge building culture. This too is not a surprise. Much PD – even when it is longer than afterschool or a half day – tends to compress the amount of time spent on a single idea. For example, traditional professional development would likely introduce the idea of "knowledge building community" once and not revisit it, in the name of efficiency. But understanding does

not grow by singular exposure to an idea. Instead, it takes time or, as one participant put it, "ideas need to percolate."

Experience What Students Experience

As noted earlier, participants began their NGSX experience conducting a science investigation in a cohort led by experienced facilitators who were intentionally engaging group members so the cohort might become a knowledge building community. As we alluded to above, participants repeatedly noted that they liked "the process of learning first from the student perspective," "it was very useful to experience it first, and then move to the other side of the desk" (7.30.2015). "It was eye-opening to walk through as a student, to start unsure with my ideas and building understanding" (11.8.2016). "I really enjoyed being a student in the first days" (7.30.2015). "Actually doing what the kids would do was useful. Then we were able to experience the questions, frustrations, and knowledge building personally" (7.29.2015). Another notes: "Knowledge building must be experienced to be understood. If we want teachers to be able to do this in their classrooms, they will need to have an experience of it themselves as learners."

> It has completely changed how I will be teaching. The biggest impact occurred during the first week when we were taught the way we are expected to teach. By actually playing the role of the students, I learned how truly beneficial this approach is and, knowing what I got out of the experience, I don't think I could ever teach the "old way" again. (7.30.2015)

> Starting with our student hat on was a great way to see exactly how this will look in our rooms and gave us a feel for what our students will feel like in the fall. I am leaving here with a much better feel than just how to go from the standards to a well-planned lesson. (7.30.2015)

Another teacher remarked, "By experiencing [the teaching] myself, I can better see how it should look in my own classroom" (7.30.2015). "I thought the first three days that we spent with our student hat on was eye opening and thought provoking. It forced me to sit and experience the science practices first hand as a student. It reminded me to keep activities engaging, discussions fruitful, and content focused" (7.30.2015). And another notes: "I liked the perspective of being a student because it reminds me of what kind of learner I am. I like hands on, talking, and seeing. I'm not auditory and I'm not real patient."

These participant comments highlight how the experience of being a student in a science investigation helped some participants develop cognitive empathy for their students, as well as seeing a model for what an investigation might look like. But how to pull such teaching off, and understanding the components of the experience don't get much attention in participants' early comments. It seems more that participants have some vague sense of the spirit or the gestalt of the experience without (yet) digging into the challenges of teaching this way.

The Technology of Knowledge Building Facilitation: Talk Moves

Recall that, typically, the Facilitator Pathway was interwoven with the Matter Pathway (see Figure 2). When the teachers moved from the Matter Pathway into the first part of the Facilitator Pathway, they were introduced to technical language to help them name and deconstruct or decompose their "student" experiences (e.g., Grossman et al., 2009; Janssen et al., 2015). One core idea was "academically productive talk" (Michaels & O'Connor, 2012; Michaels et al., 2008; O'Connor & Michaels, 1993, 1996), a concept that refers to talk that is focused on meaningful academic content, and involves listening to others and articulating one's reasoning (Engle & Conant, 2002). Academically productive talk is not a "natural act" (Wineburg, 1999) but learned behavior that takes skill and practice. The facilitators-in-training examined transcripts, their own experience, and videos to identify teaching moves that encourage academically productive talk, as well as reading research-based materials curated by the staff.

A central idea was "talk moves," different strategies teachers use to deflect talk from themselves, shifting the responsibility to continue the discussion onto the students (see Table 2). The NGSX design leaned heavily on this idea, and participants learned about several distinct "talk moves," including: (1) giving people time to think; (2) asking, "Can you say more?"; probing ("So, you are saying . . . ?"); (4) asking someone to rephrase what a peer has said; (5) asking for evidence or reasoning ("Why do you think that?"); (6) asking for counterexamples ("Does it always work that way?"); (7) asking others if they agree or not; (8) adding on ("Can anyone add on to what she just said?"); and (9) explaining what someone else said ("Who thinks they can explain what he just said?") (Michaels & O'Connor, 2012). The NGSX designers used talk moves not simply because their practicality and usefulness appealed to teachers, but also because they map well on to the science practices of communication, explanation, reasoning with evidence, and argumentation.

Thus, talk moves became a hook for digging into ideas about academically productive talk and facilitating knowledge building communities, abstractions that went well beyond knowing what to say at a given moment. For the next two to three weeks of professional development, participants and their facilitators worked on and returned to these ideas. This happened in the form of reflections on the six different learning activities participants engaged in: listening to facilitators think aloud, watching videos, reading additional material, and practicing talk moves in large group and fishbowl settings. At some point in the PD, participants began to notice (and record) variations on talk moves that were modeled in their discussions by their facilitators or in videos that they watched:

Talk Moves	Sample of Talk Moves Observed in Group Discussions and Videos
(1) Wait time	
(2) Asking, "Can you say more?"	- Say more
(3) Probing, "So, you are saying . . . ?"	- But does anyone think that it is kind of weird? - What do you mean by. . .
(4) Asking someone to rephrase what a peer has said	- Let's hear from some other people who haven't said much lately . . . . - Can someone rephrase that?
5) Asking for evidence or reasoning, "Why do you think that?"	- What do you think? Do you have an idea?
6) Asking for counterexamples, "Does it always work that way?"	
(7) Asking others if they agree or not	- So, with that in mind, what do you think?
(8) Adding on, "Can anyone add on to what she just said?"	- Okay, who can add to that . . . . - Anyone else want to add to that?
9) Explaining what someone else said, "Who thinks they can explain what he just said?"	So, you are saying that . . .

Table 2. *Sample Talk Moves*

Building a Broader Pedagogical Practice

But talk moves were the tip of the iceberg. While short term PD often focuses on providing teachers with curricular or instructional tools (sometimes referred to as "make-and-take"), NGSX was designed to contribute to the development of the group's broader practice. Here we define practice in the fourth sense of the word that Lampert (2010) describes:

> The dictionary tells us that among all its other meanings, practice can mean "the carrying on or exercise of a profession or occupation, esp. of law, surgery, or medicine; the professional work or business of a lawyer or medical man." . . . Learning the practice of teaching in this sense is learning "what teachers do" in common rather than learning what a particular teacher does by apprenticing with a more proficient individual. It is about more than acquiring skills or best practices. It involves adopting the identity of a teacher, being accepted as a teacher, and taking on the common values, language, and tools of teaching. (p. 29)

As the NGSX PD progressed, participants began moving beyond taking notes on backpocket prompts to principles to guide their talk and their action. As one participant noted:

> I now have a deeper understanding of how important what I say and do is, how it impacts my effectiveness as a facilitator. For a group of people to build a stronger knowledge base, they need to trust each other, take responsibility to support each other, and help guide each other to a deeper understanding. (7.11.2016)

In reflections, facilitators-in-training sometimes offered observations in the form of mantras or hints that they would pass on to colleagues. The most frequently mentioned "dos and don'ts" included (see Table 3):

Theme	Dos	Don'ts
Monitoring pacing and timing	Wait it out – climate and manner are more important than time Have prompts in your back pocket to deepen or propel a conversation	Don't be rushed
Managing one's own behavior	Suspend judgment, be a questioner Talk less and ask questions more Leave space for students to speculate and feel comfortable with ambiguity and questioning their assumptions	Don't say what your students can say – allow the participants to do most of the talking
Modeling ways of being	Model vulnerability Be neutral/non-affirming	
Having a clear eye on the goal	Explicitly encourage voices Focus on meaning making, not the right answer Ask participants to restate what they think is going on Draw out more thorough explanations from a variety of participants	Don't supply information, ask for clarification Don't do the thinking for the group – the participants need to do the work of explaining, rephrasing, and connecting. Don't explain, let them do it Do not collect a bunch of right answers – build knowledge
Central Commitments	Listen carefully - remember that all comments are valuable	Don't give up on the participants Don't be an evaluator

Table 3. *Participant Nominations for the Dos and Don'ts of NGSX Facilitation*

The list is an intriguing compendium of the multiple vectors along which a teacher is working while managing classroom discourse (Lampert, 2003). Monitoring pacing and timing is one theme (don't be rushed, wait it out); managing one's own behavior is another (talk less, suspend judgment, be neutral). Modeling ways of being is central (model vulnerability); having a clear eye on what the goal is yet another (build knowledge, draw out more thorough explanations, focus on meaning making). There are also central commitments/principles (don't give up on participants, all comments are valuable). Other observations focused on more general personal capacities: "My appreciation for the role of culture has deepened. It's a culture of

respect for one another, trust in one another, and patience with a slow moving, inclusive process. There are challenges for facilitators and participants including stamina, thoughtfulness, and mental agility" (7.11.2016). Participants also noted the importance of patience, curiosity, vulnerability, sincerity, "being respectful, collaborative, active, engaged, safe, open . . ." and "taking risks." "Flexibility, confidence, restraint [in giving answers]" (9.22.2015) were also repeatedly mentioned.

Other Tools for Facilitation

While participants repeatedly returned to the abstract concepts of knowledge building and knowledge building facilitation, the NGSX experience also provided them with the bread and butter of PD: concrete tools they could take back to their classrooms. As one participant notes:

> There is a pretty significant list of tools needed to ensure a pedagogy in service of knowledge building. This includes an inquiry stance where learners construct knowledge rather than absorb. No giving answers, but rather developing capacity to use clarifying and probing stems that encourage and support struggle with conceptions, tools to engage all learners, clear learning goals . . ., and responsive unscripted facilitation. (4.28.2018)

This included the talk moves discussed above, as well as other instructional ideas, including exploring three types of discussion: (1) initial ideas discussion, (2) building understanding discussion, and (3) consensus discussion (Michaels & Moon, 2016). Participants also learned about a host of tools and routines that were part of the insider knowledge of NGSS-inspired teaching and learning, which became their new professional vocabulary: using stickies, constructing "summary tables" and "explanation checklists," using "Gotta Have worksheets" and "driving question boards" (e.g., Weizman et al., 2008), "posterizing," five questions/classroom routines (i.e., anchoring phenomena, problematizing, driving question, driving question board, navigation routine, storyline), and "sentence frames," all of which were used by the group in their own investigations and through both pathways. Of these tools, teachers said, We learned "very specific ideas about using tools to help make student thinking more visible . . . I am interested in more tools for teachers to use as they begin to implement slowly" (11.13.2015). "It was really helpful to have concrete tools for implementing in the classroom… Essentially these tools put the big overarching concepts into practicable application" (6.11.13.2015). In this sense, the tools played the same kind of role the talk moves did, as a hook that allowed for both something practical that participants could hold on to, while being concrete instantiations of more complicated abstract ideas and theoretical commitments.

Participants' learning involved going back and forth between articulating specifics and weaving them together to create the broader pedagogical practice of identity, beliefs, tools, norms, commitments, culture, and vocabulary; recall Lampert's fourth definition of practice as a combination of "common values, language, and tools of teaching") (see Figure 5).

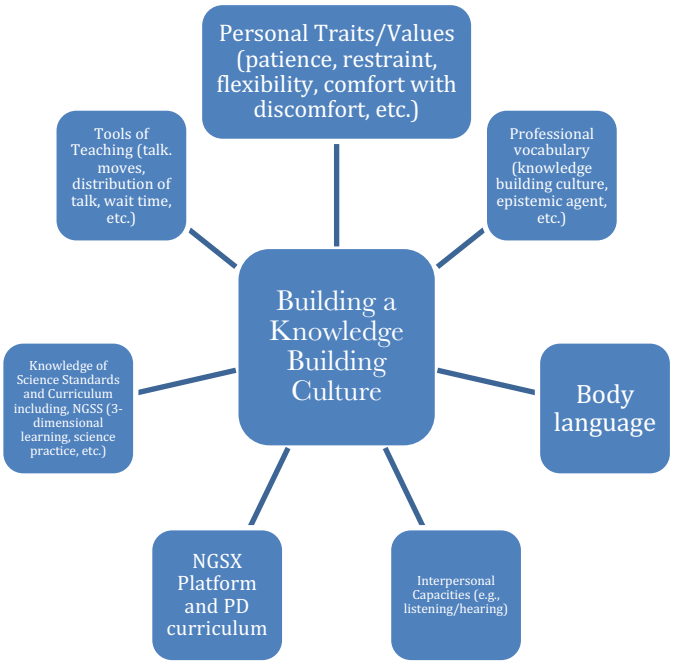

Figure 5. *Foci of Facilitator-in-Training Learning*

Participants reported observing and learning about this collection of dispositions, skills, knowledge, resources, and the like, gradually. Different facilitators-in-training learned different things, at different times, through different aspects of the PD. They also gradually started putting these ideas together: "the amount of wait time the facilitator provided, and the way she continually drew participants into the conversation by inviting, waiting, resisting the urge to explain and respond herself. … questions and misconceptions were allowed to surface, the facilitator asked the participants to address these, did not answer the questions or resolve the problems herself" (7.11.2017). One participant compared it to directing a student orchestra: "The director doesn't play the notes for the participants, but guides and leads them toward collaboration. It takes practice to facilitate these discussions, but teachers will find choosing and applying the appropriate move becomes easier over time" (11.9.2015). Another observed:

> Some of the things required for facilitation include building a risk-free environment of knowledge building where participants can voice questions, fears, struggles, and can validate the group's thinking and growth. It is important not to reveal answers and to take the learning moment away from participants. If we want them to build that knowledge, they need to struggle and question each other. Further questioning [by the facilitator] for clarifications builds consensus and gets them to think outside of the basic models they may have relied on for their own understanding in the past.

This participant's thinking resonates with Resendes and Dobbie's (n.d.) note about psychological safety, and using that to justify building a certain kind of learning culture. And from day one of the NGSX experience, participants were reading and hearing about these ideas. But participants' understanding took longer to develop, through talking about the ideas, watching them unfold in videos, and in experiencing them themselves. In that sense, taking on

the role of student went well beyond having empathy for the student experience; it also included developing an understanding of the textures of the experience from the inside.

Understanding Learning as a Social Event

A crucial turning point in participants' thinking involved understanding knowledge building as a "social event, something that 'takes a village'" (7.11.2016) and that "knowledge building is facilitated by the instructor, but it must be owned by the learners because it is their knowledge that matters." "Knowledge building is collaborative . . . synergistic. The group is more powerful than the individual . . . no end to the growth or directions that one can go in." "Building knowledge is communal, so the idea is that both participants and the facilitator are building knowledge together" (9.22.2015). "Knowledge building is a group and interactive process, not solely an individual one" (09.22.2015). Facilitators were responsible for making this happen.

Central to the communal, social nature of knowledge building was the relational trust needed for all group members to engage in authentic learning. As one participant noted:

> My idea of knowledge building has changed and developed. I am more conscious of the culture necessary to have effective knowledge building. I think I have been so focused on content that I haven't thought about building the knowledge for everyone and that first you must find out where everyone is and what their thoughts are. (11.22.2015)

Others make similar comments. "Knowledge building is about building relationships . . . as much as it is about building content knowledge" (09.22.2015). It is a process of "building a climate and culture of trust" (09.22.2015). "Before I thought knowledge building was about getting someone to understand a concept. Now I understand there is a lot more, building a positive culture for learning" (4.28.2016).

In the end, participants learned that building a community and orchestrating knowledge building is hard work: "There is no wiggle room for flying by the seat of your pants . . . that's scary . . . Knowledge building will look like a conversation in the classroom, but it will appear to a casual observer to be fairly random. Indeed, it is not . . . The class discussion IS the learning" (4.28.18). Or as one participant put it: "talk is not an add-on" (7.15.2015); "learning floats on a sea of talking" (11.1.2015). Facilitators-in-training reflected extensively on the nature of the knowledge building communities they would be eventually teaching teachers to create:

> It requires a learning culture of risk-takers willing to share ideas and not worry about being wrong. Participants build on and connect with others' ideas by listening, questioning, and challenging ideas with evidence. Knowledge building facilitation is a way to guide/direct participants to the learning goal by supporting them, encouraging co-construction of ideas and digging deeper into concepts. Facilitators are not the know-all expert of the group, but a supporting member. (1.16.2018)

> If a person is going to be able to take risks with their prior and developing understanding, there has to be a culture in place. Knowledge building is not a lone person, but a complex process that involves diverse ideas and experiences. For people to identify their confusion

> is very powerful, not only for them but it also pushes them to listen to the ideas of others and to connect it to their learning. (9.22.2015)
>
> You have to go public to create community. . . . Encouraging intellectual risk taking and not worrying about confusion, and feeling like you need to resolve it immediately. It is okay to be in the place of not knowing.

Many things are entailed in getting facilitation "right." One has to – over time – create a knowledge building "culture," which is – in many ways – antithetical to what most teachers and students experience in schools: "Learning can only happen in a risk-free environment, where making mistakes is not a bad things but a learning opportunity." "It takes developing a strong culture of respect and risk taking"; "building a culture where students can feel safe being wrong so that thinking can be made public"; "building a risk-free environment where participants can voice questions, fears, struggle, and can validate the group's thinking/growth. . . . If we want them to build knowledge, they need time to struggle and question each other" (6.6.2015). Participants observed that this type of culture requires people to "listen, share, reflect, critique, and challenge in order to figure things out." They understood the facilitator's job as not to confirm the participants' answers, but to have others in the group give additional information based on evidence from experiments. Specific talk moves were part of one's professional repertoire; "they need to be seamless, second nature….. I have to use them fluidly."

Theme 2: Helping Others Weather Change

If developing a complex understanding of knowledge building communities and the broad pedagogical practice one needs to be a NGSX facilitator was one theme of participants' perspectives, a second theme involved understanding the changes in the status quo both of science teaching and science teacher PD, and learning how to support NGSX participants in weathering that change.

As experienced teachers and – for some – experienced PD leaders, participants knew that building a knowledge building culture among teachers – and helping them learn to build a similar culture among their students – would be challenging. In general, they had faith that, in the end, students would "love talking to each other in this way" and teachers would find the NGSX content relevant and useful. But getting to that point is challenging:

> Right now, I am thinking most about the culture building that will support these tools. Developing a classroom where students and teachers alike are motivated to push forward, share publicly, use sticky notes and summary checklists all in the interest of truly and deeply being able to explain phenomena is no small task. The realist in me knows that not all adults are willing to put in the effort . . . and I think students are just as susceptible. I want to figure out the culture piece, so these efforts are truly engaging for students and not simply another thing they do for the sake of compliance. (11.13.2015)

Here we describe the challenges that the facilitators-in-training most often mentioned in PD discussions and their reflections.

The Right Answer

The tyranny of "the right answer" was a central challenge: "The habit of 'right answer' is so embedded in our education process that I foresee my biggest challenge as a facilitator will be to keep conversation going . . . This allows for an assessment of where all of the individuals within the group are in their understanding, not just a few spokespeople" (9.22.2015). "As teachers, when we hear the answer we are looking for, we move on" (9.22.2015); "I am concerned that time pressure and learning goals push me to 'say too much' rather than allowing the participants to grapple with ideas… I also worry that participants come to a workshop expecting to be told stuff and don't want to be forced to think" (6.6.2015). As one participant reflected:

> I often facilitate with my outcome in mind and stop discussion when part of the class demonstrates their understanding by contributing orally. I am very interested in slowing down, listening and making sure that the students have time to contribute, and that they truly understand the concept. Important skills for an NGSX facilitator are personal deep knowledge of the students and confidence in leading the group through discussion. (9.22.2015)

Time

Time was another challenge. Participants agreed that this kind of deep learning and the teaching being envisioned would take time. And no one thought that that was inappropriate. They acknowledged that they needed to "allow time for participants to think" (9.22.2015); "to leave time for people to think and restate"; "to balance time, for this is a struggle . . . . (9.22.2015). Time has always been an issue for teachers: "Time crunches and the need for the right answer often guide both teaching and learning" (7.17.2015). "We can feel rushed because of time constraints and how long it may take to teach with an inquiry model that we don't ensure understanding" (9.22.2015). "Taking time is key. Slowing things down, allowing for silences and pauses, and not being intimidated by it." "In my experience, adults are more inclined to want to be given the right answer or be told what to do. The nasty four letter word of TIME comes up so frequently, that adults are missing the point that it takes TIME to think deeply about their own learning" (5.23.2016).

But slowing things down meant un-doing old habits, and learning new ones: "It takes a huge amount of time, something I am not used to giving up"; "Wait time sounds easy but it is not. As a teacher, I tend to always want to fill the pauses. It is a really difficult thing to learn but can be very powerful." "Giving the group time to talk things out so that the facilitator had time to really understand what was happening and where the group was struggling and knowing when to interject is helpful." As one participant noted:

> I hear the right answer early in the discussion. It is easy then to assume that this perspective is shared and understood by the whole group. I need to learn to continue to probe, ask for restatement, ask for further explanation. Keep probing and trust that the resulting discussion will be richer and will involve more learners.

Developing sound professional judgment is key: "How much do you push to continue to gather ideas? Once you get a sense that the right ideas are popping up and you push longer for

deeper understanding, are you confusing others? Where do you draw the line?" Questions arose: "How do I make this work in a 48 minute hour?" "How do you manage these practices inside a 45-minute class with 27 students, three times in one day?" "Can we take short cuts?"

But classroom time was not the only way that NGSX took time. The planning would be "consuming," (11.29.2017) "it is going to take a long time to develop a unit! Unpacking matters! (11.29.2017); "This takes time! We need to make time to work collaboratively!" (11.29.2017). "It certainly is going to take a lot of time, trials, and brainpower to develop storylines and units, meaningful tasks, and elements involved in the process" (11.29.2017).

Working with Adults

Another challenge involved working with adults. The challenges of encouraging productive talk were also important for the participants to explore: "Too often people refrain from sharing their thinking because their thoughts may not be fully developed" (11.9.2015); "making sure participants don't feel insulted or embarrassed" (1.13.2013). Teachers are busy people, with a lot on their plate, "getting teacher groups to slow down, put school issues (teacher evaluation, class size, student challenges, etc.) to rest for the time being" requires a facilitator who can "keep positive, constructive, and reflective energy in the group" (10.24.2015). "Adults have many other things on their plates, and to take a day off from all of that to support their own learning is difficult" (5/18.1016). "There are people right now during this PD that we are in on their computers not making the right choices."

> It is okay to be brave and to try out ideas regardless of if you are sure of them… I think it is hard to trust that through the process of discussion, a better understanding will be built. It seems that people are often afraid to state their ideas because they don't want it to seem as if they don't know something, but the power of this approach is in exploring and learning together. (10.27.2015)
>
> Making thinking public can be even more challenging for adults than kids sometimes. The fear of being embarrassed can be a really strong motivator to stay quiet! (1.13.2016)
>
> Really challenging for adults! We are not used to thinking out loud, exploring an idea, even if we may be totally wrong. The NGSX facilitators have done a tremendous job at modeling norms and how to enforce them and …. talk moves. (1.14.2016)
>
> I am nervous about getting teachers to be open about making this paradigm shift. It will really make them feel vulnerable in terms of not being the expert in their classrooms. It is also a shift that will require a great deal of practice (implementing talk moves, facilitating, etc.) and I see a great importance in providing ongoing PD and support after they engage in NGSX. (11.14.2015).

Facilitators-in-training also worried about whether all teachers would find NGSX professional development immediately relevant. They expressed concern with (some) teachers' desire for "make-and-take" or "spray-and-pray" PD: "It is frustrating for me when teachers prefer the sit-n-git style of professional learning (which isn't learning at all)" (9.22.2105). "Most

PD participants are still looking for things to take back to the classroom and use right away" (12.15.2015). One participant reflected on a group discussion:

> I'm still reflecting on our recent discussion …. About whether we provide practical PD which teachers can "use in their classrooms tomorrow," or PD that helps them dive deeply into the 3-dimensional nature of science presented in NGSS, with all of its associated discomfort and anxiety. I still wonder if it's not a false dichotomy, that is, an either-or proposition. Or can we do both simultaneously? (11.14.2015)

One participant reported:

> It took time for our teachers to understand that the activities they participated in in our PD sessions weren't prepackaged, ready-to-use lessons for their classrooms, but rather, immersive experiences intended to help them deepen their content knowledge, reflect upon their learning experience, and examine their instructional strategies in a shared context. That said, they seem to truly value the strategies and tools we have shared with them. (1.13.2016)

Equity: Unlearning Beliefs about Students

Finally, NGSX designers firmly believe that all students can learn challenging science and collaborate in creating new knowledge. This foundational program tenet has required that facilitators help participating teachers learn to think differently about their students, both in terms of what they are capable of, and in terms of students' position in the classroom and curriculum. Ideas about students' capacity included comments like: "We don't give the kids enough credit" (8.5.2016). "Students have better questions….more thoughtful" (8.5.2016). Teachers noted that students were more willing to ask questions that were outside of the box. "The students' questions were better than ours. They are more focused on understanding odor." "The students' questions are more fascinating than ours. Ours are teacher-centered and the kids are curious. We kill curiosity because we keep our teacher hat on" (5.26.2016). "I was blown away by student ideas, but never heard their ideas like that before!!!!" "Students of all age groups are more than capable of digging deeper into an idea and arguing their stance as long as there has been sufficient preparation" (1.15.2017).

The NGSX vision of teaching and learning positions students (individually and collectively) at the heart of classrooms. This too provoked participants to re-think how they positioned students in their classrooms. Participants' comments included observations like: "The biggest change in my thinking is making sure that students are involved in communicating their thinking and their ideas with each other" (2.16.2017). "I need to be very cautious about allowing the learners to learn, let them do the figuring out, and only facilitate their sense making" (11.14.2015). "I have been more open to allowing students to work on their own models of the concepts we are studying without guidelines or parameters. It is my instinct to want to help guide them or to give hints or help. Instead, I allowed them to work through and come up with their own ideas and representations" (2.16.2017). One participant noted that he needed to allow "students to develop their understanding without automatically jumping in and telling them what is right" (2.15.2017). "Allowing learners to experience the struggle of learning is critical" (9.22.2015), another notes. Another participant said:

> Students really need to be given the time to make a prediction, but also to say it out loud or write it down, and give reasons. I see how this makes them invested in what happens next. They should also address others' ideas and give evidence. The biggest change for my thinking is how much more time I should devote to this. (2.16.2017)

Other participants make similar observations: "Students must be the leaders in their learning and teachers must be the facilitator/guide for that journey." "We have a clearer model of student learning. That learning is a process where students interact with their own and other students' thinking, using their models, trying, checking, correcting, retrying until the parts of the model appear to behave in predictable patterns" (1.15.2017)."It is much more student-directed than the way we previously taught science. Students learn more through the process of working through the science to come to an answer they can prove rather than being given the information and do activities to 'prove' it" (2.9.2017). "Students need to be the biggest part of the lesson . . . I need to step back and stop doing so much of the science 'teaching' and put the students in the position to figure out some of the concepts for themselves before I step in and guide them to where they need to go" (11.28.2016). Another commented:

> The biggest change in my thinking is that in order for students to engage in science and engineering practices, they need to actually think! Not just follow procedures and complete a lab, but think about what they know and relate it to a new idea. If kids are invested and make a claim about their thinking and make their thinking public, there is a much higher chance they will be invested in figuring out the answer. (11.28.2016)

Removing one's self from telling students what they needed to know included leaving students to struggle: "One of the most challenging things for me is allowing students to be 'wrong' and letting them self-correct" (2.16.2017). Another notes: "A change of thinking for me is to allow students to fail when initially trying to explain a concept, observation, or phenomenon" (2 /16/2017). One participant connected her experience as a student-learner to new insights into her students:

> This course has flipped our paradigm of teaching science on its head. We now see the importance of having students discover understanding or do the heavy lifting while we guide them intentionally on their journey. What surprised us most was our own insecurity in discovering understanding while we worked on developing our own [scientific] models. Our students will also struggle in the beginning to think for themselves and being okay with not knowing the answer.

In sum, facilitators-in-training identified core challenges that they believed would arise from asking teachers who participated in NGSX to shift their ideas about science teaching and learning, as well as about professional development. These challenges included being sensitive to all educators' concerning about the limited resource of time, and how it is distributed across the curriculum, teachers' duties and work lives, and professional learning opportunities; working with adults, who have become accustomed to certain workplace and professional norms that may conflict with the culture of knowledge building communities; helping teachers adopt equitable teaching practices that are based on the assumption that all students and teachers can learn challenging content; and the tyranny of the "right answer," which teachers sometimes give

preference to in the name of limited time and which conflicts with the NGSX commitment to teachers and students collaboratively exploring ideas and phenomena in ways that presume that jumping to the right answer without giving learners' understandings to evolve leads to superficial and fragile knowledge. Developing professional traits like patience, curiosity, vulnerability, sincerity, flexibility, confidence, restraint, and an openness to risk taking were seen as important to the NGSX facilitator and teacher identity.

The Pedagogy of Professional Development

Participants' understanding of the challenges of facilitation was informed by many activities, including viewing videos, comparing and contrasting cases of facilitation, listening to uber facilitators explain their reasoning, and practicing facilitation with their peers. Of listening to the facilitators' reflections, one participant explained: "Hearing her thinking and reasoning about her choices helped me appreciate what she had accomplished here. . . . it gave me a much deeper understanding of her facilitation and talk moves than from my own analysis" (9.22.2015). Another participant noted:

> It has helped me tremendously when our NGSX facilitators have made their "thinking visible" by explaining the facilitation decisions they made during our sessions. . . .When I know why a specific facilitation decision was made, I can then apply it to my understanding and use it to guide my future facilitation. (10.26.2015)

As noted earlier, the videos made abstract ideas about facilitation concrete: "Being able to watch facilitators and then reflect on their moves has helped me turn my attention back on my own role as facilitator." "The videos really show how talk moves create an equitable and open environment for students. I particularly like how the talk moves help me mindfully offer so many different entry points to the discussion such as sharing ideas, rephrasing what someone else said, expanding an idea, or responding through agreement or disagreement" (1.21.2015). Another participant put it this way: "The videos inspired me to change from being the protector and affirmer of knowledge into someone that can participate in developing the group's understanding." The tools were essential, as they were concrete, useful resources. As one participant said, "I think my skills as a facilitator have greatly improved thanks to the tools we have been provided – talk moves, routines, template for levels of coherence, storyline process,[13] summary tables – and so much more."

Videos and specific learning activities around videos were mentioned often. "Watching the videos helps me to improve discussions in my classroom. There is always something new or a forgotten strategy that I see each time that I can incorporate into my practice" (5.5.2015). "The video clips are a great resource. They show examples and promote the feeling that it can be done" (11.9.2015). "The videos serve as mentor texts for teachers who are searching for an entry point into beginning deeper levels of discussion with students" (11.10.2015). "The videos of

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[13] The storyline process is another NGSS abstraction drawn from contemporary science education curriculum development. In NGSS, a storyline is the rationale for a set of Performance Expectations (PEs) at specific grade bands; groups of lessons are developed and sequenced to help students follow their questions about phenomena under investigation. These lessons use 3-D design (concepts, ideas, and practices).

groups struggling and facilitators working with them helped me the most. Especially the ones where we paused and asked, 'What would we do?" The discussions that followed helped me to see different strategies and points of view." One teacher summed it up: "The videos afforded me the opportunity to see this art [of facilitation] in action."

Another teacher noted, "Seeing talk moves and productive talk in action is so helpful…. Seeing productive talk in action verifies how valuable it is for students" (11.11.2015). Videos allow participants, one facilitator-in-training said, "to see the information in practice." "The videos break things down into manageable chunks and provide classroom examples of the talk moves in action" (11.11.2015). Videos "give us a better idea of what productive talk looks and sounds like in real classrooms" (11.12.2015). Another participant explained:

> The videos help me construct a mental model of how to use talk moves. Every time I watch a video of a teacher using productive talk moves to incorporate science or engineering practices, I use that visual model to help me in my discussions: probing for evidence, listening carefully, students engaging with one another. It makes an article seem real and practical… the videos are exemplars of the talk moves. (1.19.2015)

> I so rarely have the opportunity to watch another teacher in action, I appreciate being able to view targeted teaching video segments to help me come to clarity about which talk move to use when. (1.20.2015)

But while facilitators-in-training found the videos helpful, they were also circumspect: "The videos and examples make it look easy, but inside I don't feel like this is going to be easy." "The practice of facilitation is a lot more involved than it seems" (6.11.2015). Up until the very last day of their professional development, participants were still noting "I need to work on my talk moves." Participants understood that they were on a journey of learning.

Theme 3: Identifying One's Own Learning Needs

One learning teaching over a lifetime. Yet the educational system does not acknowledge the need for that on-going learning. As Cohen (1999) notes: "Teacher learning has traditionally been a patchwork of opportunities—formal and informal, mandatory and voluntary, serendipitous and planned—stitched together into a fragmented and incoherent 'curriculum'" (as cited in Wilson & Berne, 1999; see also Ball & Cohen, 1999). Further, Elmore (2000) observes, "The existing system doesn't value continuous learning as a collective good" (p. 20). Teachers are exposed to a seemingly-random set of learning opportunities, depending on the latest educational fads, or legislative mandates. Some teachers pursue their own learning in more systematic ways, seeking out new opportunities that will enhance and build upon what they learned before.

The NGSX approach go against this historical grain, intentionally launching teachers on a path of learning in which they are major authors of the knowledge and skill they develop. Unsurprisingly then, a third major theme in participants' reflections concerned their sense of what their own learning needs were moving forward. In part, this was due to prompts that were part of the curriculum; in reflections, teachers were often asked to answer questions like: "How does this relate to your classroom?" Or "What would you like to learn more about?" But, in

part, teachers' ideas about their own learning were motivated by their sense that – despite spending two or three weeks in the cohort – they were only just beginning their learning journey.

In response to these prompts, teachers gradually revealed more about their perceptions of their own learning needs, as well as their concerns and doubts (see Figure 6). This appeared to be enabled by the fact that many participants saw their own practice in the articles or discussions and – perhaps – felt validated. "I realized that I use some of the talk moves," "I already do a lot of this." "I provide many opportunities for academic talk." But they also often segued into comments about how they could improve (even though facilitators-in-training were never asked to directly speak to their weaknesses): "But I have to be more intentional," or "I have to have students dig deeper," or "I could improve using more wait time, using more talk moves." "I am not sure that I set up my classroom to allow my students to be successful, especially at the whole group discussion level" (6.9.2016). "I use some of the strategies but certainly not for the effect demonstrated in the video" (5.23.2016). "I need practice in providing questions that lead to discussion among ALL of my students" (5.23.2016). Many of these learning needs map on to the components of practice delineated in Figure 5: body language, understanding science standards and curriculum, understanding students, creating cultures in which adults can learn.

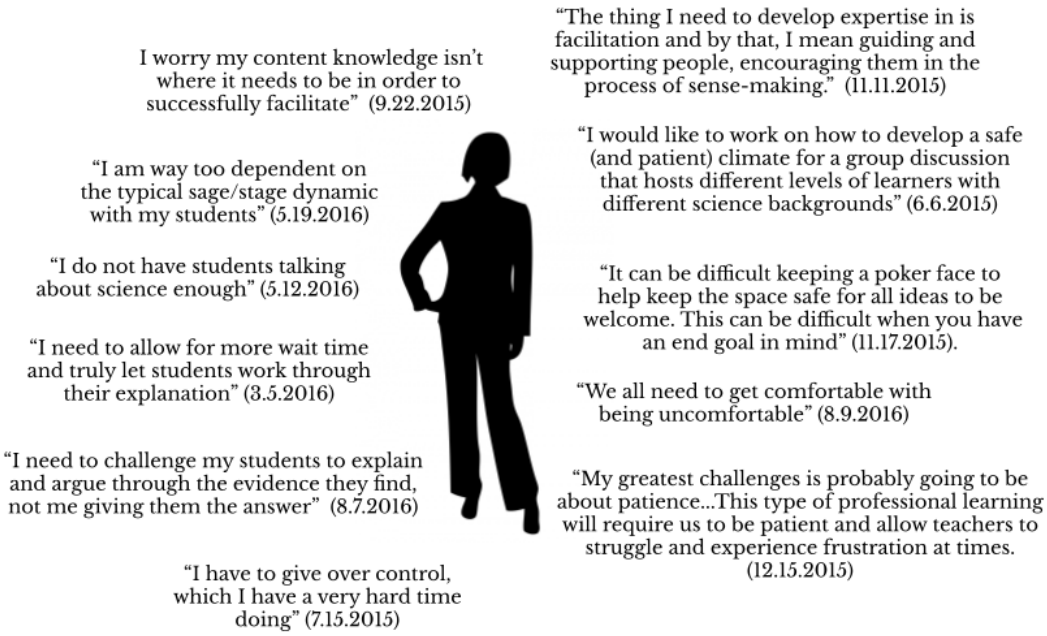

Figure 6: Reflecting on One's Own Learning Needs

Many comments noted old habits, personal preferences, and perceived workplace pressures:

> I have tried things like this in class with minimal success thus far. Because students are not used to doing this, they have a hard time engaging. I then find myself getting antsy because I know what my time frame is and what I need to get through in order to get coverage on tests, and I move on. (5.23.2016)

"Seeing themselves" often took participants aback: "It really hit home with me to recognize myself in the description of the peer leader challenged to 'do things they have not done, have not been trained to do, and have not experienced." Another participant noted: "I currently fall into the category that the article refers to as 'recitation' and students perceive that there are right and wrong answers to give. I can see that this impacts their willingness to participate" (3.5.2016). "I definitely do too much of right or wrong answer type questioning and I need to change that" (8.10.2015). "I have been guilty of the unproductive talk moves like recitation. I've asked single questions where there has only been one right answer. And then responding that the answer was correct and moving on." "I'm beginning to think more about limitations I might have coming to the table. I worry my content knowledge isn't where it needs to be in order to successfully facilitate" (9.22.2015). Others noted that they had to work on using talk moves, pressing participants to provide deeper answers, allowing ideas to develop instead of halting the discussion when a right answer surfaces. Still others thought that they had to work on their body language, and on providing others with constructive and respectful feedback. Because schools are not institutions that engage teachers in substantive discussions of content, curriculum, and pedagogy on a regular basis and because the culture of schools and of professional development also does not often include teachers being asked to interrogate their answers, or consider whether their explanations are sound or robust enough, the teacher-participants felt that their mastery of these essential facilitation skills was under-developed.

Over the course of the NGSX facilitator PD, facilitators-in-training increasingly identified specific areas in which they wanted to improve: "I need to improve my listening skills, "I need to work on containing my excitement." "Asking the best question to prompt learning . . . I look forward to getting to that point . . . but I know I have a lot of work to do." (5.19.2016). "As a member of higher ed, I am way too dependent on the typical sage/stage dynamic with my students, even when I am purposefully trying to incorporate more active learning strategies" (5.19.2016). "I would like to work on how to develop a safe (and patient) climate for a group discussion that hosts different levels of learners with different science backgrounds" (6.6.2015). "I do not have students talking about science enough" (5.12.2016). "I'm not there yet!" "I've used wait time in my classroom, but I need to use it more effectively" (3.27.2016) "I need to allow for more wait time and truly let students work through their explanation" (3.5.2016). As one participant noted:

> I need to switch more into a guided role than as a giver of information. I need to challenge my students to explain and argue through the evidence they find, not me giving them the answer. I need to get away from the kitchen labs where there is only one right answer and let them explore a phenomenon. . . I will also need to remember that it is a marathon, not a sprint, so I won't get everything where it needs to be tomorrow. (8.7.2016)

Many participants commented on the need to "give up control" (6.6.2015). Participants expressed concern about their ability to do so: "I have to give over control, which I have a very hard time doing" (7.15.2015). "I need to work on my body language and getting others to provide constructive feedback. I need to move away from being the leader to being an active participant" (6.11.2015). "We all need to get comfortable with being uncomfortable" (8.9.2016). Other participants concur:

> To make this shift, teachers first have to be willing to give up much of the control we are accustomed to. . . . . Instead of the teacher feeding the students information, the students are asking questions and are generating ideas. They are creating models using prior knowledge. . . . .Students are working together and are distributing the work and authority among themselves and the teacher. In our more traditional approach, the majority of the work was put on the teachers , as she was giving the students the information needed to find the answer.
>
> It is scary for teachers (myself included) to switch from telling students about science to letting them explore science. For years, we have lived in the land of giving science information . . . . it is okay not to have all of the answers (8.12.2016).
>
> My greatest challenges is probably going to be about patience. I believe we have conditioned as teachers to look for strategies and quick solutions to curriculum and instructional questions. This type of professional learning will require us to be patient and allow teachers to struggle and experience frustration at times.
>
> In workshops, I have been emphasizing the need for students to transition from "learning about" to "figuring out," but have not done the parallel for teacher PD – shifting from "content delivery" to "knowledge building professional learning. I hope that I will be able to more eloquently convey this to teachers as I experience it for myself during NGSX. (12.15.2015)

But Am I Ready to Take It On?

In general, participants were in awe of the facilitators who ran their sessions, and of other facilitators whose work they watched on videos. No one expressed complete confidence in their preparedness: ""This is a monumental shift and there is little chance that I will hit the ground running on all cylinders with this approach. . . . Even more challenging is how to find time to do this for all of the topics that the state mandates." But neither did participants seem paralyzed with fear. Partially, this was due to the structure of their roles: All facilitators worked in pairs, so they would never be solely responsible for running the Facilitators Pathway. Also, there was the web-based platform, with its highly structured explanations for every chapter and unit.

Perhaps more importantly, participants saw their learning as a progression: They had a vision; they had had an opportunity to watch, discuss, reflect on, and practice both the tools they would use (talk moves, discussion question boards, summary tables, and the like); and they were part of their own knowledge building community of facilitators leading the gradual reform of science instruction in light of NGSS. They also knew that learning to facilitate would "take some time" (11.11.2015); "using science talk moves will take some practice and experience" (10.24.2015); "it will take a lot of practice and preparation" (10.24.2015). "I know a lot more now…. Which makes me realize how little I actually know. Basically, I feel more informed and I have a better understanding of NGSS, but now I realize how very much I am going to have to create, find, think about, etc." "I know I will make mistakes and not everyone will buy in to the NGSX philosophy, but some will, and I will continue to grow as well. I find calm knowing I am in good company. I would love to stay in contact with our cohort."

Other participants made comments that resonated:

> When watching great facilitators at work, they make leading these types of discussions seem effortless. Knowing that it really is such a complex process can make embarking on this type of thing feel very daunting. However, we're gathering up tools to help us and I think just diving in and trying these things out will be the best way to develop expertise. (10.24.2015)

> I'm sure the first and second rounds of facilitating discussions will be on the rough side, but I'm confident that the overall experience for teachers will be positive. (10.24.2015)

> I do not expect to be at the [my facilitators'] level right out of the gate, but I do feel that I have been provided with the tools and resources necessary to be successful. Even the small things, like providing us with agendas and planning sheets that we can edit for our own needs are very useful and help make this task seem more manageable. (11.14.2015)

> This will be my first time in a new role as a facilitator, yet the comprehensive and thoughtful design of NGSX reassures me that I can do this and that there are resources I can turn to if need be. (11.14.2015)

One participant's comment captures the anxiety and exhilaration: "While the unpredictable nature of discussion is a bit unnerving, it is equally exciting" (11.14.2015). Many participants planned to "start small and build along the way" (9.22.2015). Another's comment resonates: "We must take baby steps with a sense of urgency" (11.14.2015). "I'll need more practice" (5.18.2016). "The acknowledgement that it is not going to be smooth sailing all of the time made me feel more comfortable" (8.25.2015). "I hope to work on my own comfort level with leading colleagues and peers through this. And hope to remember that I don't have to be the expert, but am working to help them make meaning" (3.21.2015). "Facilitation, like good teaching, is an art form and requires practice. I am eager and nervous – like the first day of school each year – to try things out and improve my craft" (9.22.2015).

That said, some participants reported feeling chastened by what they considered their own naïve expectations about planning. As seasoned teachers, perhaps they took for granted their ability to on-board quickly, despite the NGSX reading materials inclusion of a challenge concerning NGSX facilitation preparation: "I had not thought about how much preparation is needed in the task of leading discussions" (10.21.2015). "In regard to leading discussions -- no matter what type – I am reminded of the importance of planning and preparation" (10.24.2015). Other comments included:

> This has been an incredible experience. [My facilitator] did an amazing job of pushing us to really work and push ourselves. We were all pretty much sure we had this down, and then we started working! The set-up of the program was that we had to immerse ourselves in the process and truly learn. It was valuable and meaningful. (7.30.2015)

> I naively thought facilitating this discussion would be relatively simple. After observing our [colleagues who volunteered to try facilitating our discussion] and proceeding

> through the chapter steps, I realized that I will need much more preparation and practice to achieve the clarity that I hope to capture from participant discussions. (10.23. 2015)

Participants were grateful for the many materials provided by NGSX. In addition to the carefully laid out steps and activities and suggested time allotments in the online learning system, facilitators also had access to sample agendas and annotations of the sessions created by experienced facilitators.

> Through our practice facilitations, I am feeling much more comfortable with using the talk moves. . . . I appreciate the detailed agendas, room descriptions, and material lists to prepare for facilitation. That is a HUGE support in that I can work more on the practice of facilitation instead of planning all of the details necessary to make the event happen. (11.14.2015)

Participants also had plans for how to continue learning. Many of them planned to "keep a copy of the talk moves accessible"(11.9.2015); "I look forward to doing the audio recording so I can get some real feedback before attempting to facilitate these discussions . . . that will help me organize my thoughts about employing appropriate talk moves in particular situations" (10.24.2015). "It is going to be imperative for me to continually review/revisit and use the talk moves!!!!" (10.24.2015). As one participant said:

> I want my clipboard with my talk moves sheet and the three types of discussions sheet shortened to one page with the questions on it along the paper to write notes while leading discussions. Definitely filming myself leading various discussions so I can go through a descriptive protocol first with it (just the evidence, no judgment) then work to fix what I want to fix. (10.24.2015)

All of the participants thought that learning to facilitate would take time and practice, and would involve making mistakes: "We have gained some understanding of many great tools and strategies, but it remains our challenge to practice and come to own these as facilitators. I am gaining confidence and look forward to more opportunity to practice. I expect to continue to make regrettable moves in the future, but I accept that they won't kill anyone and in the process, I will grow in my abilities." "The only way to [engage] is to dig in, try. Evaluate, revamp efforts, and to keep plugging away. It seems overwhelming…. It's a struggle that will take time and effort." Another said: "I now know what to strive for, but I have to also recognize that developing these skills will take some time."

Central also to the professional development is the intentional creation of a cadre of teacher facilitators within the relevant state. In the case of State 1, this group already existed through the development of professional development hubs during earlier systemic and standards-based reform. In Connecticut, the cadre had to be created, building it – for the most part – with experienced K-12 teachers who were interested in becoming teacher leaders and who had been participants in regional professional development projects. As members of the broader "guild" of teacher leaders (Shore & Wilson, 2005), each cohort of new facilitators was socialized into seeing their colleagues as an important professional resource. As one participant noted, "the colleagues in this group will be a wonderful set of resources" (11.14.2015). "This is one of the most outstanding group of people I have ever worked with." (11.14.2015). "I find calm knowing

I am in good company. I would love to stay in contact" (11.14.2015). Many mentioned the NGSX group as a resource: "This group has been great support for my learning" (11.14.2015). "I am very happy to have participated in this community! Between the established norms and the palpable respect for the process, I sense our study group community is well positioned to practice." One participant put it this way: "There is a lot of experience and professionalism in this room. I have appreciated what I have heard from my colleagues. . . . I had many wonderful in-depth conversations with the professionals at my table." Another participant reflected:

> The one thing that makes me feel more confident is that I have had the pleasure of working with what I feel is one of the most outstanding groups of people I have every worked with. The number of people who are willing to help and to let me visit and talk with them, share materials they have developed, and – in general – made me feel more comfortable is amazing. (11.14.2015)

In the end, participants were chastened but excited, generally worried about their ability to pull this off in the first PD sessions they led but enthusiastic about the ideas and their newfound deeper understanding of NGSS. The professional community that they had developed helped in this regard, for they felt confident that they would eventually master the talk moves, and that as knowledge building facilitators, they themselves were learners who were allowed to make mistakes and learn from them. In fact, that vulnerability might make them more credible leaders. "Facilitators are not the know-all expert of the group, but a supporting member" (1.16.2018). And while there were certainly participants who left less enthusiastic about NGSX than their peers, many were excited, if daunted.[14] As one participant put it: "My first posts included words like 'panic' and 'apprehension.' but now my focus has shifted, and I began to see that knowledge building wasn't something to be afraid of but something that was doable" (9.22.2015). Other comments include:

> Practicing the talk moves and the what-would-you-do-next activities and the "how would you handle this situation" activities were very helpful. The first few rounds of facilitations will involve developing my comfort and command of the material and delivery style of the PD. I will need to consciously practice and model the tools for knowledge building facilitation, which may feel uncomfortable in the beginning, especially in pushing participants to take ownership of the process.
>
> Of course, there is much to learn still, but I feel as though I have the tools and the vision framed up by NGSX. Now I need time to plan, reflect, plan some more, collaborate with cohort members, prepare, think about, gear up for, plan, reflect, and finally facilitate the first day with a new study group. Reflection and practice will continue to help me grow and become more skilled in knowledge building facilitation. As for what contributed to my "confidence," I'd say just letting go of many of my logistical concerns and thinking deeply about the experiences with each unit and chapter. I know I will make mistakes and not everyone will buy into the NGSX philosophy, but some will, and I will continue to grow as well. I find calm knowing I am in good company. I would love to stay in

[14] A limitation of this analysis is that it relies heavily on the written documentation of teachers' perspectives. Less enthusiastic participants might have felt uncomfortable expressing their concerns in reflection.

> contact and be a resource for anyone in our cohort and I hope we'll share our experiences and resources as we move forward. (11.14.2015)

> While there is no doubt that the process is challenging, but it can have many positive results. It will be a time when highly trained educators will learn to establish a learning community where all are respected and where deep knowledge is encouraged. Insightful, knowledgeable exchanges will result in confident, collaborative teachers. Could this possibly lead to more high respected educators in our communities? (10.21.2015)

In general, participants felt empowered by the professional development, and daunted both by how much there was still to know, and nervous with anticipation of the early stages of putting these ideas into action in their own study groups. As one participant wrote: "I feel empowered to become the kind of learner and leader I have always admired. It resonates with my personal philosophy of life-long learning. . . Change is always unsettling, but I am looking forward to setting new goals for myself as a leader, teacher, and now facilitator." Another's comment resonates: "I am relieved that as a PD leader, I will be able to practice what I preach" (6.30. 2015).

Discussion

> The NGSX experience is a real revolution for me. My entire premise used to be that I was trying to get students to articulate the "right" answer. The answer the teacher knows. No wonder their participation was lukewarm. In redefining my role, I need to step back and allow people to own their own learning. (10.21.2015)

The literature on professional development suggests that PD improves instruction when it involves teachers' active engagement, aligned with policies that create coherence, focused on specific content, of sufficient duration, and involving collective participation. Nothing presented in this case would refute those general "rules." A more recent version of this list of core features has emphasized the activities of being coached, observing models, and writing reflections. Yet when tested using quasi- experimental designs, it has been difficult to establish that there is a penultimate list of design hallmarks that withstands the rigor of quasi-experimental design and irrefutably leads to student achievement gains on standardized tests. Our modest proposal is that while pursuing quasi-experimental evidence in search of a natural law in the nomological tradition (Florio Ruane, 2002; Wardekker, 2000), interpretive research -- including thickly described cases of the meaning that participants make of the high quality professional development that they encounter – might complement -- while also expanding -- our insights into professional development and collective capacity to both design and implement PD that leads to student and teacher learning.

So how might this case study of NGSX and facilitator training contribute to our collective understanding of professional development? We acknowledge first that the data presented here do not provide evidence that the facilitators prepared in these NGSX cohorts went on to lead teacher professional development that led to changes in teachers' practice or to students' learning science in ways that correspond to NGSS visions of an educated citizenry. That was not the goal of this research. Instead, our goal was to use a thickly described case of professional development to understand the experiences from the participants' point of view. That said, in our visits to

schools where these facilitators were running teacher study groups, we witnessed classroom instruction that looked far different than traditional science instruction (e.g., NASEM, 2015): Classroom (and school hallway) walls were plastered with driving question boards (See Figure 7), summary tables (see Figure 8), and the like. Students were collectively creating Jamboards of stickie notes about their observations and questions., while other classes were engaged in discussions in which teachers had very little to say.

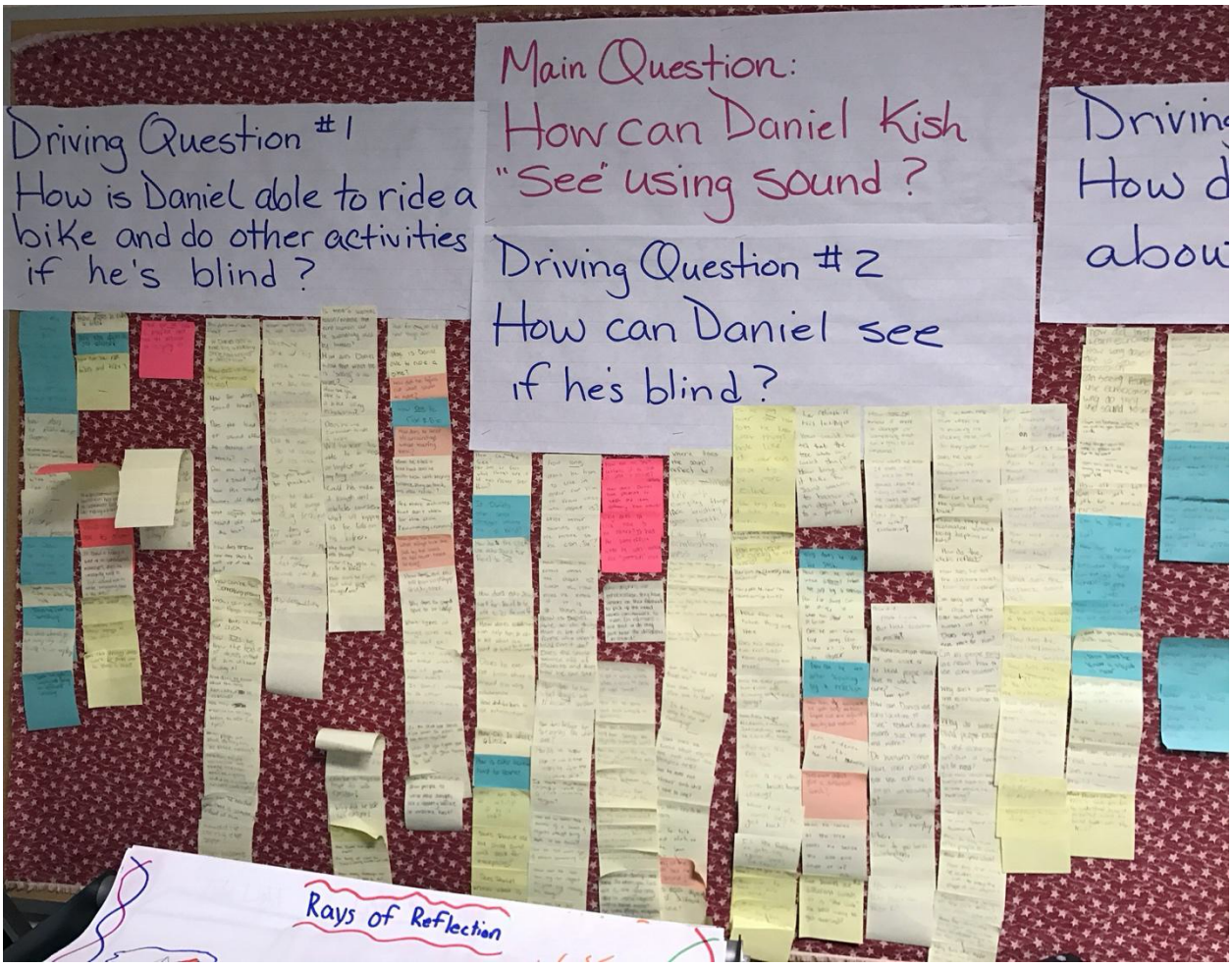

Figure 7: Sample of a Driving Question Board

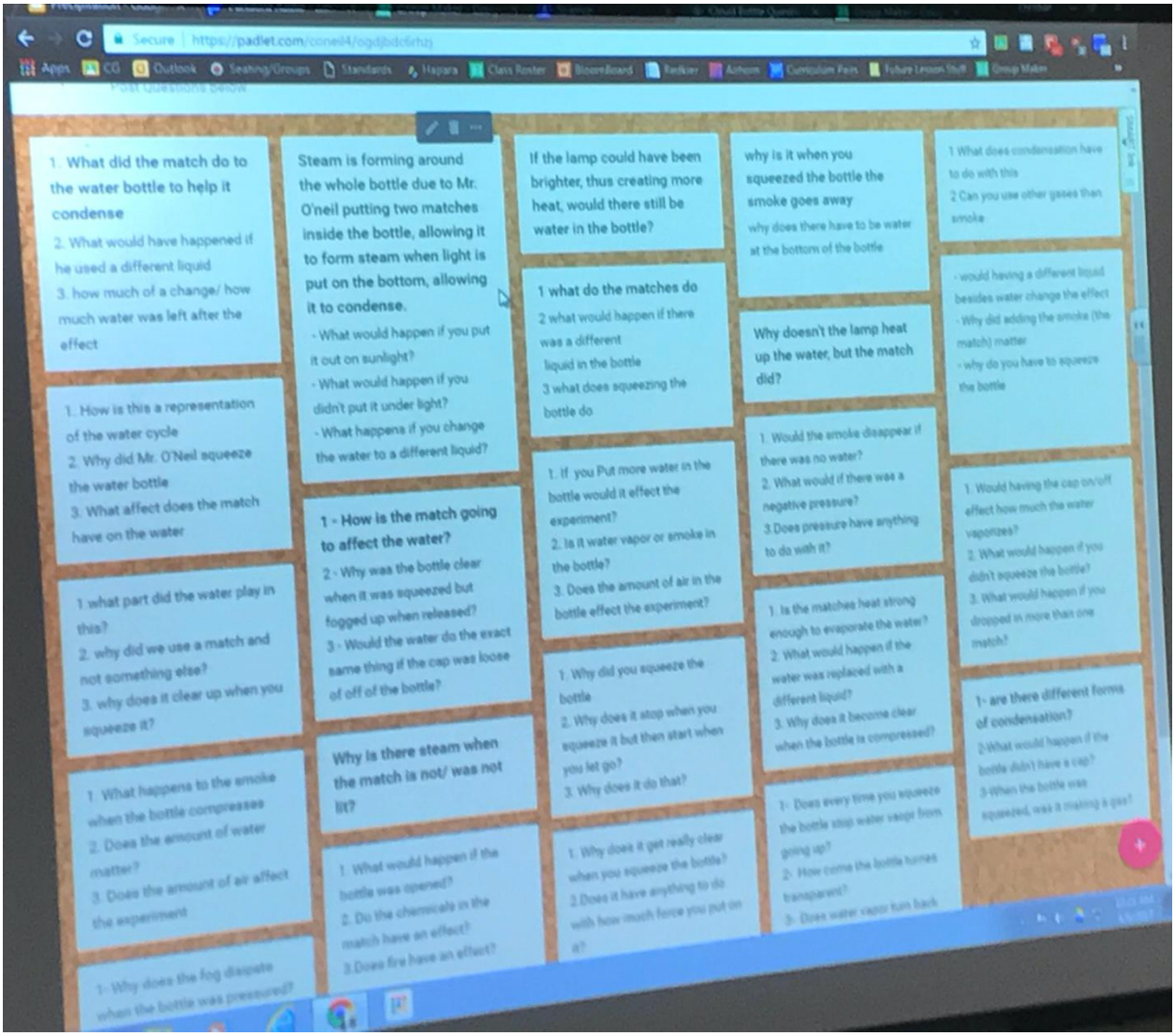

Figure 8. Class-created Stickie Board of Class Questions

We also note that the participants' comments are primarily positive. While there were occasional negative comments or "push back" on ideas and activities, the majority of the reflections and all of the field visits were characterized by a remarkable esprit des corps among participants. This is not particularly surprising: The NGSX leaders believed in truth in advertising and were very clear with applicants that the professional development focused on new ideas about science teaching and learning, as well as PD. The facilitators-in-training were selected based, in part, on their openness to exploring those ideas. The participants were also all volunteers, thus further amplifying any selection bias in the direction of a predilection for progressive ideas about reform-oriented science teaching and learning. Again, our goal is not to prove that NGSX caused facilitator learning, but to listen to participants' perceptions of how they experienced the PD, and what sense they made of it.

The facilitators-in-training tell a complex story that captures the messiness of teaching and learning and the messiness of tracing causal lines between PD and teacher or student

outcomes. They are learning different things at different rates. Their ideas evolve over time, as the facilitators witness and participate in various instantiations of knowledge building community and culture. They have lots of reservations – the time all of this takes (both in terms of covering the curriculum and in terms of changing one's teaching practice), whether they will have the administrative support they need, whether the students will be comfortable with these changes. They gain insight into their own learning needs, and they worry about taking responsibility for leading other teachers in their study groups. Despite their concerns, they stuck it out, completed the training, and went on to facilitate their own NGSX knowledge-building communities.

Four Conjectures

We begin with four conjectures we might make about NGSX and the experiences of participants in the Facilitator Pathway. First, as other research has suggested (Desimone & Garet, 2015), participants differed in what they were learning at any one particular time. Additionally, participants' understandings significantly evolved over the course of the three weeks of professional development. As we followed participants into their schools and classrooms, we saw them continue to work on these ideas. It seems plausible that their incomplete understandings will continue to evolve and deepen. That participants' understandings evolved over time illuminates the claim that professional development has to be of "sufficient duration," although what is meant by sufficient duration might be on a sliding scale: some ideas and practices are less familiar to teachers than others, or require more practice, reading, reflecting, or observing. A set of illustrative cases of what sufficient duration means in different contexts and – perhaps – illustrations of how participants' understanding and skill is still unfinished might flesh out the meaning of "sufficient duration" in a way that differs from attempting to stipulate a specific number of hours or to determine "dosage" (e.g., Kraft, et al., 2018; Pianta et al., 2014).

That said, the fact that ideas evolve over time, and on different timelines for different participants raises challenges for measuring those changes for the purposes of assessment, evaluation, or research. Measuring the effects of PD often entails finding the mean effect for individual teacher outcomes on assessments of teacher knowledge or classroom instruction. However, if each teacher is on a different learning trajectory, the search for a significant mean might be thwarted. What's more, the participants' honesty about their own evolving understanding reminds us of how long it takes to really learn something. The measures used to assess effective professional development (usually administered at the conclusion of the PD or within a year) of that conclusion. But changing one's practice is quite different than learning to use a new tool; changing practice is a long-term affair. Geertz (1973), in the same essay quoted earlier, explained that "cultural analysis is intrinsically incomplete. And worse than that, the more deeply it goes the less complete it is" (p. 29). Most of us have this experience regularly of learning how little we understand something the more we dig into it. Most research on professional development ignores this fact.

Moreover, the proxies we use for student and teacher learning are weak, and do not begin to scratch the surface of the complex set of theoretical ideas, instructional practices, and technical tools that teachers are working on and within high quality professional development. This brings us to our second conjecture: that participants' learning involved moving back and forth between abstractions like "knowledge building communities" and "academically productive talk" to concrete strategies like wait time, talk moves, and using tools like driving question boards.

The concepts gave the NGSX vision of teaching and learning meaning and purpose. The concrete strategies gave the facilitators-in-training a place to start, things to do. It was in the pairing of the technical tools, practices, and the theoretical abstractions that participants found motivation and relevance (e.g., this is worth doing) and achievable goals (e.g., I can do this).

That participants' learning went back and forth between digging into abstractions or concepts and mastering identifiable techniques might be a way of understanding why the oft-cited core features of content-focus and working with student work matter. In the case of the NGSX Facilitator Pathway, the facilitators-in-training repeatedly noted that anchoring professional development in a focused set of ideas and exposing them to concrete manifestations of those ideas helped them learn. But it was also apparent that while the facilitators-in-training appreciated the tools and techniques NGSX provided, the purpose and meaning of those tools depended on participants' understanding of core theoretical concepts like knowledge building communities and student/teacher agency. Those concepts gave the NGSX work meaning. Had the participants been told to facilitate knowledge building discussions without grappling with the purpose of those discussions, the thinking entailed in the improvisational work of managing such discussions, and the various tools that one might use to pull them off, facilitators would have been ill-prepared to engage in the practice.

A third conjecture is that participants' learning also involved taking on different perspectives through watching videos of instruction, listening to facilitator think alouds, writing reflections, practicing facilitation moves, participating in scientific investigations, reading research and other related materials, and listening to presentations by NGSX staff, either in person or on video. Some of these perspectives positioned teachers to be "inside" of a phenomenon (an investigation, being a member of a knowledge building community), while other experiences placed them outside of the experience looking in (watching videos of teaching). This array of different learning opportunities is an expanded list of the ones typically enumerated in the PD core features lists, including active learning, collaboration, expert feedback and support, and time for reflection

If one thinks of these opportunities as different facets of a prism, they each serve as windows onto visions of NGSX facilitation and NGSS teaching and learning. The combination of the perspectives captured much more of the complexity of teaching and learning than any single tool – talk moves, wait time, sticky notes – could. Teachers, and in this case facilitators, operate on numerous dimensions simultaneously. As sentient beings in classrooms, they are attending to body language, space, discourse, individual students, the collective, the content they are teaching, the social norms of the class culture. The list – to teachers – can seem endless. The emergent portrait of NGSX facilitation practice allowed for facilitators-in-training to notice how teachers used their bodies (e.g., the poker face), how facilitators used talk moves to helps their learners take more risks and dig deeper into ideas, how the physical space of a classroom was set up, how social structures (small and large groups) were managed and integrated, or what scientific ideas were understood or misunderstood. In this sense, the PD consistently kept participants immersed in instances of NGSX facilitation that were more holistic and full-bodied, and seldom engaged in reductive analysis of facilitation that focused on single dimensions of the practice.

What is more, the case illustrates how these individual immersive, robust opportunities -- when combined -- create a learning culture in which participants did the joint work of building their collective knowledge. Rogoff (2014) differentiates between "assembly line instruction," which is prevalent in U.S. schools and entails controlling learners' attention, motivation, and behavior in settings isolated from the places where one might make authentic contributions to a community and "learning by observing and pitching in," whereby participants learn through collaborations in which they are motivated, keen to contribute, and doing authentic work. One might argue that the NGSX learning culture is one of learning by observing and pitching in. Its norms of participation are designed to build and sustain trust and respect; norms of inquiry that use experimentation, models, argument, and explanation; and values like sharing the floor, patience, and generous listening. We have noted repeatedly that a major driver for this was the need to model for teachers the kind of learning culture they would need to create for their teacher study groups, and that those teachers would later need to create for their students. However, it was equally important that this learning culture is a very different kind of professional culture than most teachers or teacher leaders typically experience. Recall Geertz's (borrowing from Weber) conceptualization of culture as webs of significance that humans spin for themselves. We note here that NGSX – through both the Matter Pathway with teachers and the Facilitator Pathway – is promoting a view of professional culture that empowers teachers as constructors of the knowledge necessary to work on the on-going improvement of the educational system. This perspective gives a particular meaning to the idea of professional "networks" that goes beyond nodes and connectors, and involves the discourse and purpose of those networked communities.

This leads us to our final conjecture: that participants (the facilitators, their uber-facilitators, and the NGSX designers) were positioned as knowledge-builders, not knowledge-receivers; they were also socialized into doing this work as a member of a collective with responsibilities to that larger group (e.g., the importance of respect, trust, patience, openness, contributing to everyone's learning, etc.). This positioning gave facilitators agency, which is essential if teachers are then to be committed to giving their students' agency as well. This shift in position is not an either-or: people who produce knowledge also consume knowledge, building on previous work, but in ways that emphasize its critical consumption. The facilitators-in-training were provided with a range of resources: research articles, instructional tools and strategies, sample learning activities, and theoretical ideas. They were encouraged to make meaning of them, to try the resources out, to voice concerns and criticisms, and to put them together in idiosyncratic ways. They were also encouraged to build new knowledge of both facilitation and NGSS-aligned teaching and learning. These aspects of the PD are closely aligned with the core feature of teacher "active engagement," here in the sense of minds-on: rather expecting facilitators to absorb new information, they were asked to work with it, integrate it with their previous understanding and skill, critically respond, and raise questions. That said, our portrait peers inside of the work entailed to designing and enabling opportunities for minds-on engagement among teachers.

We do not propose these conjectures as additions to the list of core features offered by various scholars: content focus, active learning, sufficient duration, coaching and expert support, the use of models, and the like. Instead, we see the following four observations as themes of the narrative – or case -- we offer here,

- that participants are on different individual learning trajectories that are circling around the work of the collective;
- that participants' learning goes back and forth between mastering specific, concrete tools and strategies and developing understanding of the theoretical abstractions that give those tools purpose and meaning;
- that the gestalt of the PD is comprised of taking on different perspectives (as learner, as teacher, as facilitator) through learning opportunities that act as different lenses onto the PD's central ideas; and
- and that the participants are positioned as knowledge builders whose work is sustained and nurtured in learning cultures that value their ideas and experiences.

We do not argue that the field needs to abandon the search for the best set of nomological or paradigmatic (Bruner, 1985) propositions about effective professional development. Indeed, such research can continue to provide important insights (Wayne, et al., 2008). But we do suggest that thick cases such as this one provide an important complement to that form of knowledge, as they capture the dynamics of professional development and the meaning that participants took from their experiences. As Bruner (1985) argued: "The imaginative application of the narrative mode leads instead to good stories, gripping drama, believable historical accounts. It deals in human or human-like intention and action and the vicissitudes and consequences that mark their course. It is essentially temporal rather than timeless" (pp. 98-99). While the story we tell here does not lead to a set of propositions that can be directly applied to a new context, it might prepare researchers or PD designers to theorize about how to put the core features together in productive ways and to anticipate what combinations of activities will increase participants' engagement and learning. Our story might also help PD designers in other contexts anticipate what combination of design principles and activities (as expressions of these principles) will increase participants' engagement, learning, and willingness to try them out and hone them in classrooms over time.

The design and enactment of high quality professional development is professional work, requiring professional judgment. Professional judgment, across many professions – law, finance, medicine, business – is informed by multiple forms of knowledge, including natural "laws," as well as cases or exemplars (Shulman, 1985). Our hunch is that the pursuit of a definitive list of core features of PD that will transcend time, place, and other relevant contexts is indeed chimerical and that cases of particular professional development programs that document the meaning that the participants make of them are an equally important part of our pursuit of insight that will help us wisely invest material, financial, human, social, and time resources in continuing to build the educator workforce's capacities.

Appendix

Facilitator Pathway:
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