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The *Next Generation Science Standards* (*NGSS*) and its parent document the *Framework for K-12 Science Education* (National Research Council, 2012) are the products of decades of research on how students learn science, and reflect the growing scholarship on the knowledge-building practices that characterize the discipline. The *NGSS* is presented to the science education community as a carefully designed yet imperfect text, as a promising lever for change but insufficient to that task without other parts of the system accommodating the effort. Pre-service preparation is a key part of that system.

But the context for preparation that exists today is itself in need of reform. Currently, "instruction about instruction" in many pre-service preparation programs is largely under-informed by the knowledge bases on teacher or student learning (Rand, 2002; US Department of Education, 2008). The quality of teacher education in science varies widely from one program to another, and in many programs there are few opportunities for learning about evidence-based teaching methods (Adams & Krockover, 1997; Clift & Brady, 2005). Novices' exposure to pedagogy is often limited to the past experiences, skills, and worldviews of their instructors and cooperating teachers (Ball, Sleep, Boerst, & Bass, 2009; Deussen, Coskie, Robinson, & Autio, 2007; Little, 1990), and what is learned is haphazard. These conditions, in many ways, are not the products of choices made by individuals in programs, but rather they emerge from a larger system of constraints that are inherent to the culture of teacher education and to gaps in the field of science education research. For instance, problematic issues include the lack of opportunities for teacher educators to learn from one another, the absence of a shared "core set" of PK-12 instructional practices, and the limited use of effective teacher education pedagogies (e.g., deconstructing and modeling instructional practices, allowing opportunities for rehearsals of practice by novices, creating beginners' tools for the design of instruction, providing principled feedback on attempts at practice).

We suggest that the *Next Generation Science Standards* be considered an opportunity for the professional development of pre-service educators. We describe below how this document might be used to expand the pedagogical repertoire of those who teach teachers of science. First, however, we describe the limits of the *NGSS* in terms of guiding instruction.

The *Next Generation Science Standards* Do Not Tell Us How to Teach

The *NGSS* tells us what kinds of ideas should take center stage in classrooms and they feature science practices as the active context for student learning. But the *NGSS* provide little insight into how a teacher might design and enact learning experiences for students. We must rely on other literatures that fill in the gaps to inform teaching methods, primarily about how to support

all students' learning of science. There are principles of powerful teaching for which strong consensus exists among researchers and knowledgeable practitioners. Among these are:

- organizing instruction around intellectually substantive and complex phenomena rather than taking a "basics first" approach (see for example Lehrer & Schauble, 2005; Palincsar & Magnusson, 2001),
- eliciting students' ideas on a regular basis to shape instruction (see for example, Hammer, Goldberg, & Fargason, 2012; Minstrell & Kraus, 2005).
- making students' thinking visible so that their ideas/reasoning/experiences become resources for others in the class (see for example, Michaels, Sohmer, O'Connor, & Resnick, 2009; Radinsky, Oliva, & Alomar, 2010),
- providing tools that allow students to revise their thinking over time (see for example, Passmore, & Stewart, 2002; Schwarz et al., 2011).
- scaffolding talk, reading and writing—in particular students' attempts at evidence-based explanations (see for example, McNeill, 2009; Smith, Maclin, Houghton, & Hennessey, 2000),
- making explicit the "rules of the game" with regard to academic discourse and its relation to everyday language (see for example, Mercer, Dawes, Wegerif, & Sams, 2004; Nasir, Rosebery, Warren, & Lee, 2006), and
- fostering meta-cognition as a habit of mind (see for example, Bransford, Brown, & Cocking, 2004; Brown & Campione, 1994).

Our point here is that the standards are only one resource for preparing educators about instruction. And as history shows us time and time again, depending upon someone else to develop curriculum that supports rigorous, responsive, and equitable teaching is naïve. This is the work that is now before us as a field and a large part of that work will be to prepare pre-service teachers for the challenges ahead.

Implications for Pre-Service Instruction

Studying the framework. The NRC's *Framework* document (2012) is a learning opportunity for pre-service teacher educators. This document lays out the rationale for why particular science ideas, scientific practices, and cross-cutting concepts were included in the *NGSS*. Even more importantly it describes research about students' science learning that can inform a teacher educator's theories of action about instruction. If pre-service educators could study the basis for the *NGSS*, it would help them refine their own pedagogy and become more flexible in how they adapt instruction to different grade levels or science domains. They should read the *Framework* with colleagues who share responsibility for science preparation and develop a set of conceptual frames or tools that can guide some of their programmatic work and teaching. The *Framework* contains references to many of the original research texts that explain, at length, ideas about instruction, learning, or science itself.

Constructing a sharable portfolio of ambitious practice. Just as there are scientific practices and teaching practices, there are also practices that are characteristic of teacher educators. These include modeling strong examples of science teaching to novices, showing how to attend to the thinking of students, and providing feedback to novices as they attempt to approximate instruction. The work of teacher educators includes instruction about curriculum materials and their design and about assessments and their relationship to teaching and learning. All of this

must now be considered within the context of the *NGSS*. How would teacher educators develop these new understandings of practice? A compelling idea might be to expand one's horizons in a public school classroom—for teacher educators themselves to enact a unit of instruction consistent with the *NGSS*, and doing so with young learners. We think of this, again, as an opportunity for professional development.

We imagine that a pre-service educator might collaborate with a local teacher to plan together a unit of instruction that is based on the *NGSS*. They then teach the unit together, documenting students' learning across time, reflecting on lessons and revising their thinking about what to teach next. Artifacts from the unit could become part of a portfolio of learning. What would be included? Planning documents, lesson plans that are annotated with notes about how students responded to instruction, formative assessments, tools that were developed to support the science practices, and video of key lessons. The portfolio could be shared with critical friends, who offer feedback and encouragement. This whole process can be a rich learning experience, but it can also be humbling. The benefits, however, far outweigh the short-lived discomforts. We imagine how powerful it would be if a group of science teachers and teacher educators did this together, if they could learn from the experiences of their collective, develop a shared language about this type of teaching and even sets of tools to support novices in doing their own classroom work.

Sorting out how NGSS fits in with past reform efforts. Teacher educators can help novices understand the *NGSS*, but these novices will then be interning in schools where the faculty have likely wrestled with an assortment of previous reforms. Teacher educators will need to make clear connections between documents like *Taking Science To School* and the *NGSS*. For example, the four proficiencies listed in *TSTS* are entirely consistent with the goals of *NGSS*. On the other hand, the de-emphasis of the idea of "inquiry" and the new focus on scientific practices (from the *Framework*) can be seen as a conflict with what was championed in earlier reform documents (i.e. the previous *Standards*, the *Benchmarks for Science Literacy*, etc.). We recommend that the science education community create straightforward statements about how the *NGSS* fits with current and past reforms, and that this document be made available to teachers and teacher educators. If cooperating teachers do not see the links and distinctions across these documents, it will be hard for them to mentor their interns using the *NGSS* as one guide for the design of instruction.

The suggestions above signal that science teacher educators must *engage* with the *NGSS* in substantive ways that go well beyond familiarizing themselves. They would benefit greatly from professional development that is contextualized in settings similar to those their pre-service students will encounter.

Unresolved Issues

We see two issues, invoking both opportunity and concern that will become more prominent with the adoption of the *NGSS*. The first of these deals with accountability. Part of pre-service apprenticeship includes being evaluated by others, both on the basis of students' test performances and on classroom observations. These evaluations can influence their employment prospects and their professional status. But we do not yet know if or how these evaluation measures used by principals or teacher education supervisors are going to be "tuned," at least in

part, to the goals of the *NGSS*. We don't know if the widely used Teacher Performance Assessment will be made consistent with the *NGSS*. And, we do not yet know how state level science tests will change and what it will imply for learning to teach. There is plenty of uncertainty to go around, and much of it is because the *NGSS* do not tell us how to teach, but rather what is important to teach. Until clear images of ambitious and equitable teaching come into focus for the science education community, we will continue to struggle with how we evaluate novices, provide feedback, and as a field, engage in the continual improvement of teaching.

The second issue is as problematic in scale and consequence as the first. At the elementary level, science in many districts is not even part of the curriculum. Some students are not exposed to science until the fourth grade or even middle school. We are seeing first hand in our own research enormous inequities emerging between those who have access to rich science experiences early in school and those who don't. This is essentially programming our students for failure. The present moment seems to be our best chance to raise the profile of science at the elementary level, perhaps by linking it with literacy and mathematics. Teacher educators at the elementary level could take the lead in articulating what the *NGSS* looks like in PK-6 classrooms. Case studies might include integrating the full range of Common Core areas— science, reading, writing, speaking, mathematics. Such a goal brings us back again to the challenge of inferring the kinds of teaching required to realize the goals embodied in the *NGSS*.

Summary

The *NGSS* provides opportunities to re-consider how we educate teachers. Every stakeholder is a learner in this picture, but none of what we recommend here can happen through the efforts of individuals working alone. This is not about tweaking the science education system; the preparation of excellent educators is a systems-level phenomenon. This means that entire institutions and the actors, resources, norms and practices that make up these systems must coordinate this effort to change. Sharing a clear vision of rigorous and equitable teaching would be a strong first step.

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