The Beginner's Repertoire

A Core Set of Instructional Practices for Teacher Preparation

Mark Windschitl I Jessica Thompson I Melissa Braaten
David Stroupe I Christine Chew I Biz Wright

University of Washington
http://tools4teachingscience.org

Paper presented at the annual meeting of the American Educational Research Association, Denver, CO, April 2010.

This material is based upon work supported by the National Educational Association Foundation, the Teachers for a New Era Project sponsored by the Carnegie Corporation, Annenberg Foundation and the Rockefeller Foundation, and the National Science Foundation under Grant No. DRL-0822016. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of these organizations.

Abstract

Recent calls for teacher education to become more grounded in practice prompt the questions: Which practice(s)? and perhaps more fundamentally, what counts as a model of instruction worth learning for a beginning professional? Currently it is difficult to identify what gets taught during teacher preparation; we do know however that visions of practice vary dramatically from one institution to the next, depending largely on the personal knowledge, experiences, and worldviews of instructors and mentors in the field. In this report we argue the following:

> *1) There are no commonly acknowledged sets of K-12 instructional practices in the various subject matter areas that the field of teacher preparation would consider "core" to the success of new educators.*
> *2) In addition, the current preparation of educators, especially in the area of instructional methods, is under-informed by knowledge of how young people learn and uninformed by knowledge of how novice teachers learn to teach.*
> *3) If a defined set of subject specific high-leverage practices could be articulated and taught during teacher preparation and induction, the broader teacher education community could collectively refine these practices as well as the tools and other resources that support their development in novices across various learning-to-teach contexts.*

These high-leverage practices would comprise a recognizable "beginner's repertoire" that is grounded in important learning goals for all K-12 students, the literature on how students learn, and emerging longitudinal research about how novices learn to teach. This effort would be part of a larger agenda, that of developing an evidence-informed system of learning opportunities, tools, and formative assessments tailored to the needs of teaching novices, that could support their continuous movement towards effective and equitable classroom practice. The following story of our work with teachers over the past five years is focused on experimentation and innovation with such practices and tools in secondary science, but the lessons learned are easily translatable to other subject matter areas.

Reinventing parts of teacher education no longer seems optional. Chief among the targets of change has been the way new teachers are taught to mediate the learning of others. Critique from inside and outside the field has challenged the theoretical nature, rigor, and relevance of instruction in preparation programs, and suggested that more emphasis be placed on the development of classroom practice (AACTE, 2010; Grossman et al., 2009; Hammerness, Darling-Hammond & Bransford, 2005; Levine, 2006). While there are some cautionary interpretations of what this could mean for the design of preparation experiences (for example the technical reductionism of the work of teaching, promoting industrial models of training), we believe that a principled focus on practice opens up an important opportunity for the teacher education community, one that is both responsive to current policy pressures around accountability and one that allows a leadership role in reforming preparation. In more explicit terms, the opportunity here is the development of a science of performance improvement for early career educators[1](Bryk, 2009; Cobb, Zhao & Dean, 2009; Raudenbush, 2008; Cohen, forthcoming), meaning an evidence-informed system of learning opportunities, tools, and formative assessments tailored to the needs of teaching novices, that can support their continuous progress towards effective and equitable classroom instruction. The foundations for this endeavor include defining a set of practices in each subject matter area that are fundamental to support K-12 student learning, and that can be taught, learned, and implemented by those entering the profession. In turn, those who teach teachers would need special forms of knowledge for such skilled practice and understand the demands these types of instruction place upon beginning educators (Grossman & McDonald, 2008).

In this report we argue for the development of a set of core instructional practices that are limited in number and represent broadly applicable instructional strategies known to foster important kinds of student engagement and learning. These practices would not replace novices' experiences with assessment, curriculum planning, use of material resources, etc., but rather they would act as an organizational framework within which these other components would be explored during preparation. The basis for this proposal is not new—Darling-Hammond (2010, p. 40) for example has already pointed out that exemplary preparation programs "[help] candidates learn to use specific practices and tools that are then applied to their clinical experiences" (see Boyd, et al., 2008; Louisiana Board of Regents, 2008). However there have been few published accounts of how core practices and a suite of supporting tools might be developed, or the local consequences of implementing them in a preparation program.

To explore the idea of a core and its associated instructional assets, we describe here the testing of a *beginner's repertoire* for secondary science teachers, embodied in a set of high leverage practices that have been associated with equitable and ambitious pedagogy. The early story involves twelve teaching novices whose thinking and practices were chronicled for more than three years. Their struggles and successes in taking up ambitious practice informed not only our designs for a beginner's repertoire, but also a system of tools and socio-professional routines that could foster such teaching over time. Thus, we also introduce initial accounts of a second cohort of teachers, whose learning is now being shaped by this core and the tools that support it.

Background

There are few obvious agreements across teacher education programs about effective K-12 classroom practices in the various subject matters and only isolated discussions about effective practice in courses that prepare novices to carry out instruction. We know little, for example, about preparation that occurs in methods classes (Clift & Brady, 2005). We have no clear picture of how they portray effective practice, nor of the pre-teaching experiences these courses provide (Grossman et al., 2009). In a broader inquiry into curriculum in teacher education, Levine (2006) found that eclecticism was the rule at both the program level and in methods courses where classroom strategies were the focus. It seems the only consistency across programs is that most preparatory experiences remain teacher-centered, focusing principally on instructional procedures and management strategies (Adams & Krockover, 1997; Freese, 2006) and less in terms of student thinking and learning.

Contributing to this lack of consistency across preparation programs is the underutilized knowledge base for teaching (Cohen, 2007; US Department of Education, 2008; Rand, 2002) which precludes, among other things, a common language around valued classroom practices and theory of how novices learn to design and enact effective instruction (Heibert, Gallimore, & Stigler, 2002). As a consequence, there exists no professional curriculum to prepare teachers. Rather, opportunities for teacher candidates to learn about classroom practice are constrained by the past experiences, skills, and personal theories of their instructors and cooperating teachers whose courses are often designed without the benefit of evidence-based understandings of what novices should learn or how they learn (Ball, Sleep, Boerst, & Bass, 2009; Deussen, Coskie, Robinson & Autio, 2007; Little, 1990).

The lack of focus within and across preparation programs has prompted some teacher educators (for example Franke & Chan, 2007) to propose a re-thinking of how novices can begin to learn—through the development of a set of *high-leverage instructional practices* for use in K-12 classrooms that can be taught to and implemented by beginning educators. This set of practices would be grounded in important learning goals for K-12 students, in the literature of how students learn, and in emerging longitudinal research about how novices learn to teach (Nolen, Ward, Horn, Childers, Campbell, & Mahna, 2009; Thompson, Windschitl, & Braaten, 2009). We further suggest that these be taught, supported, and assessed in some consistent way across all early learning-to-teach contexts as novices move from university coursework, to student teaching, and into their first years of professional work.

Our vision is that high-leverage practices (HLPs) make up the core repertoire of ambitious teaching. Ambitious teaching aims to get students of all racial, ethnic, class, and gender categories to understand key subject matter ideas, participate in the discourses of the discipline, and solve authentic problems (Lampert & Graziani, 2009; Newmann & Associates, 1996). This kind of pedagogy is both adaptive to students' needs and thinking, and maintains rigorous standards of achievement for everyone in the classroom, enabling learners of all backgrounds to succeed at high-quality work (Fennema, Franke, Carpenter, & Carey, 1993; Hill, Rowan, & Ball, 2005; Lee, 2007; Rosebery, Warren, & Conant, 1992; Smith, Lee, & Newmann, 2001; Warren & Rosebery, 1996).

This proposal will require a cultural shift in how learning to teach is conceptualized by all stakeholders in the system of preparation. Popular images portray classroom instruction as independently creative and shaped by artisanal efforts that defy prescription (Cohen, forthcoming). In this view, good teaching, rather than being a product of specialized knowledge, appears to be a set of behaviors "picked up" through the accumulation of on the job experiences (Jackson, 1986; Murray, 1989)—a stance that reinforces the current "bias against detailed professional [teacher] training" (Ball & Forzani, 2009, p. 497) and, when designed into preparation experiences, faithfully reproduces well-intentioned amateurs.

To move any practice-based agenda forward, these folk theories have to be replaced with more accurate language and images of teaching as requiring a complex of skills that can be modeled, taught to and appropriated by novices, and empirically linked with student learning. This focus on specific and accountable practice already figures prominently in the school leadership literature. City, Elmore, Fiarman, & Teitel (2009) advocate that K-12 teachers, principals, and district personnel co-develop an "instructional core" which can guide institutional efforts at professional improvement. Without it they caution, schools tend to "sanction unacceptably large variations in teaching from one classroom to another with rhetoric about instruction as style, art, or craft" (p. 188) Bryk (2009) spells out a similar theory of action around the organization for professional learning in schools:

> [An instructional system] involves some very specific pedagogical practices and social routines and expects automaticity in their use. Educators have a shared language about goals for students and understand how these align over time around some larger conception of student learning. Teachers also share a common evidence base about what constitutes learning. This allows them to analyze and refine the cause-and-effect logic that organizes their shared work. Finally, tying this all together is an explicit process for socializing new members into the community and for organizing ongoing social learning among all participants. (p. 599-600)

Both examples above represent transformations of the professional responsibilities of educators while effectively working against public stereotypes of teaching as a knowledge-weak practice.

What Are High-leverage Practices?

The idea of HLPs has been developed within the mathematics education community and in particular by Franke and Chan (2007) and Ball and colleagues (2009), whom we paraphrase here. Broadly speaking, high-leverage practices are those most likely to stimulate significant advancements in student thinking when executed with proficiency. For example, one of the HLPs that we discuss later is "eliciting students' ideas in order to adapt further instruction." This is a discourse strategy that helps teachers build upon the science related experiences and language that students bring to the classroom. The first two sets of criteria below for HLPs are based on the nature of teaching itself and on the exigencies of the teacher preparation context (from Ball et al. 2009, p. 460).

Criteria for HLPs based on examinations of the work of teaching:

- Are used frequently when teaching
- Help to improve the learning and achievement of *all* students
- Support student work that is central to the discipline of the subject matter

• Apply to different approaches in teaching the subject matter and to different topics in the subject matter

Criteria for HLPs necessitated by teacher preparation contexts:

• Are conceptually accessible to learners of teaching
• Can be articulated and taught
• Are able to be practiced by beginners in their university and field-based settings
• Can be revisited in increasingly sophisticated and integrated acts of teaching

Hatch and Grossman (2009) add that:

• HLPs should have features that readily allow novices to learn from their own teaching. An example here would be instructional routines that make students' thinking visible and that create a record of students' developing ideas and language across units of instruction in forms that allow teachers to reconcile these changes with instructional decisions they made along the way.

To this list we add two important criteria:

• First, HLPs should be few in number to reflect priorities of equitable and effective teaching, and to allow significant time for novices to develop beginning instantiations of each of these practices. If the identification of core practices for the different subject matters are considered a task that the *field* engages in (rather than an institution or instructor), then making principled choices about what is *not* going to be part of a core set will be a critical consideration. The idea is to collectively select and refine rather than to accumulate practices that comprise an instructional core.
• Second, each HLP should play a recognizable role in a larger coherent system of instruction which explicitly supports student learning goals. A single HLP, while accomplishing important aims, cannot by itself address the broader agenda of ambitious pedagogy. Moreover, a cohesive system of practices may be more likely to support an actionable *theory of instruction* for beginners than a menu of teacher moves whose whole is no greater than the sum of its parts.

Up to this point, we have talked about teaching generically, yet it is not difficult to see that deliberations about what constitutes a productive set of HLPs will take into account specific features of the subject matter disciplines. In the following section, we discuss contemporary developments in science education research that informed our choices about selecting HLPs.

What Research Contributes to the Development of High Leverage Practices?

Using literature from the subject matter area

Messages about goals for student learning in K-12 science classrooms have been consistent across all recent reform documents (summarized in National Research Council, 1996; NRC, 2005; NRC, 2007). But these messages provide only suggestions as to what teachers should be able to do, and tell us nothing about the fundamental skills and understanding required to foster valuable kinds of teacher performance. For example, Science Teaching Standard B in *Inquiry and The National Science Education Standards* (NRC, 2000, p. 22) states that "Teachers guide and facilitate learning. In doing this, teachers orchestrate discourse among students about science ideas." After reading this, teachers and teacher educators may well ask, "What does this discourse sound like?" "Who is saying what to whom, and why?" This document also offers an "instructional models" summary and vignettes of master teachers, but even these do not clearly communicate a structure for interaction among teacher, students, and ideas.

Similarly, the recent consensus publication *Taking Science To School* (NRC, 2007) points out elements of classroom activity that have been shown to support student learning goals. But again, the purpose of this document was not to serve as a reference for guiding teacher preparation by articulating details of practice. Nonetheless, this volume has done an exemplary job of summarizing the proficiencies for students and, we believe, *for teachers* who are responsible for guiding young science learners. Students and teachers should be able to:

• understand, use, and interpret scientific explanations of the natural world,
• generate and evaluate scientific evidence and explanations,
• understand the nature and development of scientific knowledge, and
• participate productively in scientific practices and discourse (p. 334).

We used this document, along with other authoritative publications in science education to begin outlining a set of candidate HLPs. However we felt we were still missing a key piece of the puzzle—a credible developmental model for how beginning teachers learn to take up, filter out, or re-invent different forms of instruction as they move through early learning-to-teach contexts.

Using longitudinal studies of teacher learning to inform HLPs

In our own teacher education program we were responsible for the methods courses, which featured an earlier, less well-articulated version of ambitious teaching. This instruction included eliciting K-12 students' prior knowledge, helping students conduct model-based inquiry, and scaffolding their explanations for scientific phenomena. From observations of former graduates of our program, we knew that no beginning teacher unproblematically emulates practices from their pre-service experiences when they move into their own classrooms, but we wanted to understand *how and why* certain patterns of practice were appropriated early in one's career. To accomplish this, we followed a group of teacher candidates through their pre-service program, into secondary classrooms as they began student teaching, then into their first year of teaching. Not surprisingly we found great variation in how they translated what they had learned in teacher preparation into their own classrooms. But what eventually informed the design of the HLPs were three challenges they all faced—each involving how to help students intellectually engage in the development of scientific ideas (see Windschitl, Thompson, & Braaten, forthcoming).

First and most fundamentally, many of our beginners could not identify big ideas to teach. By "big ideas" we mean substantive relationships between concepts in the form of scientific models that help learners understand, explain, and predict a variety of important phenomena in the natural world. Such ideas were rarely self-evident in their curriculum. Indeed many instructional units or textbook chapters were not based on important science ideas at all. Our participants however felt obligated to take mundane curricular topics (e.g. "glaciers", "sound", "solutions") at face value and not seek deeper or more comprehensive scientific ideas that could help students make sense of the many activities prescribed in the support materials. [2]

A few participants however *were* able to reconstitute their curriculum around big ideas. For example, during student teaching one novice was given a unit entitled "Batteries and Bulbs." At first he believed that it was his duty to teach the mechanics of batteries and bulbs and for his students to complete exercises in making different kinds of circuits as well as comprehend the rules that governed them. Only after teaching for several days did he realize that the underlying big idea was the transformation of energy. At that point his instructional goals shifted and his teaching was re-focused away from an emphasis on the material make-up of equipment and rote recall of rules toward having students develop and test generalizable models of energy transformations within electrical systems. Sadly, this example was a rare exception. In 73 classroom observations of participants we found only 27 instances in which these beginners made adaptations to the central topics of the curriculum, and only 8 instances in which they penetrated superficial topics or broad themes to identify more substantive ideas to teach. Most adhered to their activity-centered curricula, or merely altered minor lesson details.

Importantly, we found that *identifying the "big idea" was a critical pre-condition to trying out sophisticated forms of instruction*. There were in fact *no* instances in which a participant failed to reconceptualize their curriculum topic as a big idea and then during the course of the unit attempted some form of ambitious teaching.

The second challenge for our beginning teachers was sustaining science discourse in the classroom. Our participants often knew how to get student conversations started (with a puzzling question or demonstration) but would report to us that they "didn't know where they were headed" in the ensuing discussion and perhaps more importantly they were unclear about what the purposes of the discussion should be. This was due in part because they had no guiding framework for engaging students in talk that was productive in terms of developing science ideas and equitable in terms of opportunities for participation by all students. When debriefing with participants after observing their classes, even we as instructors were unable to rely on a shared language and set of expectations with them about the classroom talk, and there was little to anchor our productive reflection together.

The third challenge for participants was the "gestalt" nature of their curricular visions for making day-to-day decisions about instruction—meaning that they tried to plan lessons based on broad themes like "student ownership", "critical thinking", or "relevance," but these were too loosely conceptualized to translate into practice. The themes functioned like slogans rather than organizing frames for classroom activity. Even though we had provided opportunities for participants to engage in approaches like Model-based Inquiry themselves as learners during the methods class and had supported them in designing lessons around this investigative paradigm, many of them retained only a vague image of this kind of instruction, perhaps because it was just that—an "approach" rather than a set of practices.

In contrast to those participants who relied on such broad themes, about a third of the cohort was able to take up multiple elements of ambitious practice over a two year period. These were individuals who developed an early curricular vision that *focused on student thinking*. These individuals engaged their students regularly in the work of hypothesizing, unpacking their current science understandings, model-building and developing evidence-based explanations. Moreover, they accomplished these things despite departmental pressure in their schools to cover content and cooperating teachers who would not support this kind of pedagogy.

Based on this knowledge of novice thinking and performance, we reconceptualized the methods course by focusing on high leverage practices that not only converged on equitable and ambitious pedagogy, but addressed the three challenges we witnessed for our participants. Equally important to us was considering how this set of practices could be fostered across the full continuum of learning-to-teach contexts—the kinds of settings that are notorious for "washing out" the effects of teacher preparation (Zeichner & Tabachnick, 1981).

At this point, one might fairly assume that our group made a deliberate decision to create a set of core practices in response to the longitudinal findings previously described. This was not the case. Our first response was to imagine the potential impact of well-designed pedagogical tools that could address what we now recognized as major impediments to novices taking up ambitious forms of teaching. We soon realized that the effectiveness of specialized tools were bound to be dependent upon the pedagogical focus and conceptual cohesion of the teaching practices the tools aimed to support. Our conversations about tools and about the practices they could support became inseparable. Only later did we begin to consider the broader impact of core practices and their associated tools on our local support system of teacher education stakeholders—the pre-service teachers, other instructors in our program, university supervisors, and importantly, our cooperating teachers (discussed in a later section).

Constructing High Leverage Practices

We identified four practices that fit the criteria described earlier for HLPs. We limited the number of HLPs, given that each of them would require the support of specially developed tools, multiple opportunities for rehearsal and feedback in different contexts, and participants' reflection on performances of that practice. It is important to distinguish our version of HLPs from others described in the literature. Ours are not tied to particular subject matter topics or developing discrete skills in students, rather, they are planning or enactment practices that aim to engage learners in different forms of classroom discourse that lead to and embody learning. These are "meso-level" practices, meaning patterns of instructional moves in which various micro-level practices (such as offering targeted feedback to students, asking a student to explain her thinking, or presenting key parts of a scientific model to students) are strategically combined to allow students to participate in recognizable genres of learning activity. Importantly, each of the practices was designed to play a role within a broader, coherent approach to ambitious teaching. This system we referred to as the *Science Learning Framework* (SLF—Figure 1).

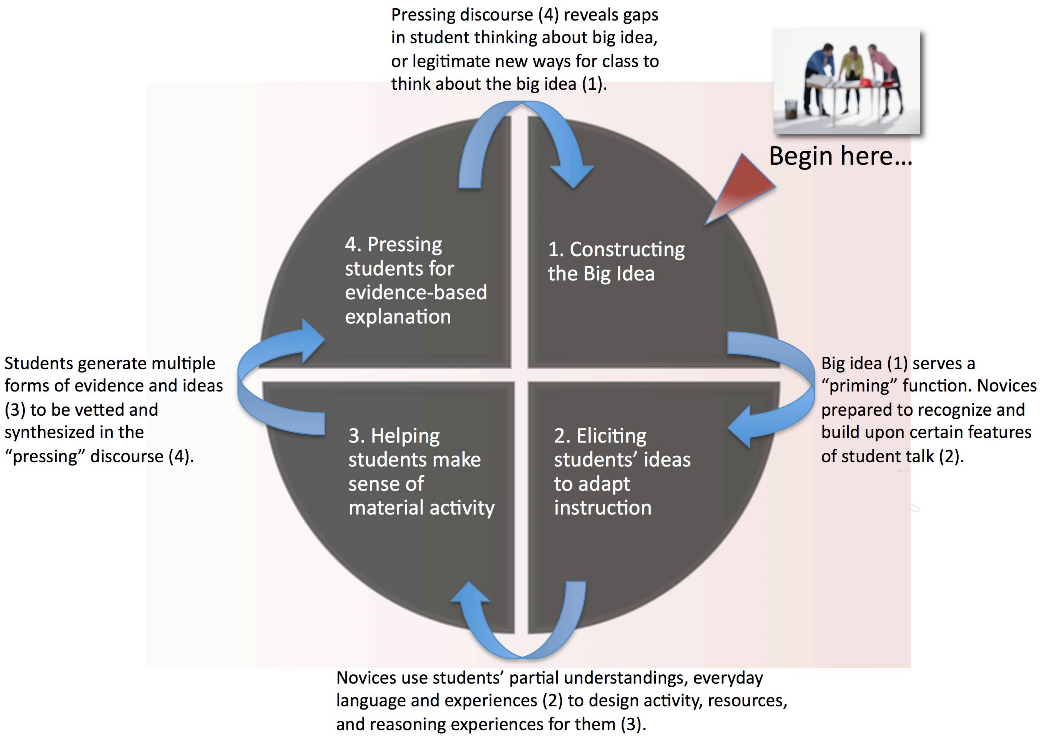


Figure 1. Pedagogical connections among the four high-leverage practices making up Model-based Inquiry

Another intentional design feature was to represent teaching through the Science Learning Framework in ways that could *not* be easily absorbed into overly simplified theories that beginners often use to think about instruction, such as cycles of lecture-lab-lecture-lab-test, or The Scientific Method. We wanted to make it difficult for participants to laminate any problematic existing ideas about organizing instruction onto our SLF, and discourage them from glossing over strategic planning and instructional moves built into each of the component practices. In other words, *we intended to frame-shift how our participants thought about organizing instruction*, *and to socialize them into new visions of "good teaching."*

The first of these HLPs is a planning practice referred to as Constructing the Big Idea. The remaining three are enactment practices that we frame as discourses rather than behavioral routines or even lessons. These are: Eliciting Students' Ideas to Adapt Instruction, Helping Students Make Sense of Material Activity, and Pressing Students for Evidence-Based Explanations. For each of these four practices we developed a tool that guided participants' planning, enactment and reflection upon lessons.

Constructing the Big Idea

This planning practice was promoted as the first step in designing any unit of instruction. We believed that designing a tool for constructing a big idea—one that encouraged the same kind of thinking that expert educators invoke in planning units of instruction (Penuel & Gallagher, 2009) —would be crucial in supporting the development of this HLP. The tool we designed, referred to here simply as the Big Idea Tool, was intended to help participants develop an explicit and elaborate understanding of the target ideas they were to teach, and to do so in terms of explaining a natural phenomenon that students could relate to. The tool is purposely low-tech, consisting of an electronic document in which participants can type in responses to a series of prompts and that can be revised as new ideas come to light. The tool begins with our description of "what counts" as a scientific idea worthy to build a unit around. We wanted to discourage the notion that a big idea could be captured in a single word or phrase like "heredity," "force and motion," or "volcanoes." Instead, we portrayed big ideas as relationships between some *natural phenomenon* and its *underlying causal explanation*. We used the Taoist Yin-Yang symbol to show the conjoined nature of the relationship and asked participants after using the tool to write or draw their phenomenon and explanation into the upper and lower halves of the symbol respectively. One example of a big idea for a Gas Laws unit involves a railroad tanker car that imploded after being steam cleaned. The explanatory model for this puzzling phenomenon combines the observable (heated steam, rapid implosion, etc.) and the unobservable (molecules of different types inside and outside the tanker moving at different speeds, creating collisions with the walls of the structure) to create the kinds of evidence-grounded storyline that authentic science values.

The Big Idea Tool scaffolds the kinds of thinking that experienced teachers engage in when trying to locate and re-package fundamental ideas of importance within common curriculum topics—ideas that are actionable in terms of designing instruction. The first task for participants using the tool is to find different resources that can help them more deeply understand whatever phenomenon, concept, or theme is listed in the curriculum, and locate references to the topic in various standards documents. Following this is a series of prompts that assist the participant in translating curriculum topics from vague labels to big ideas, depending upon how the curriculum frames the topic. Put another way, we asked participants to "unpack" ideas whose importance is often assumed to be self-evident. This requires the use of *specialized content knowledge,* a construct developed by Ball, Thames, and Phelps (2008) to describe understandings of subject matter that go beyond what experts in the disciplinary fields (in this case science or engineering) would normally need to carry out their work. For example, if the curriculum lists tangible entities as the topic (batteries and bulbs, acids and bases, plants, types of rocks), the participant responds to the questions: "Should details and facts about these 'things' be the target of study, or are there more fundamental processes associated with these that kids should understand?" "Are these things worth studying because they are part of a larger system of activity?" and "What aspects of these things might be relevant to kids' lives?"

When participants have wrestled with these questions and are beginning to coalesce substantive science ideas from the topics offered in their curricula, they then select a rich natural phenomenon/event, representing these ideas, that their students can develop explanations for over a period of days. This could be anything from earthquakes to patterns of heredity. They then articulate in detail the underlying explanatory model with its unobservable cast of characters and its causal processes. Participants often find it necessary to move back and forth between these steps in the tool; reasoning about the later questions often requires a return to revise and re-align with earlier conceptions of the big idea.

Finally, participants are asked to consider what success looks like as students come to understand this big idea. Here they identify new phenomena that the underlying model in the big idea could also explain. They are asked to imagine "what if" scenarios or thought experiments that students could predict outcomes for using what they know about the model.

We hypothesized that unpacking the big idea with this tool would help participants construct learning goals in terms of both concepts and performances that would go beyond what is expected of students in common curriculum. We further hypothesized that, for teachers, reasoning with and about the subject matter this way would serve a *priming* function. By priming we mean that in the process of planning, teachers explicitly surface the details not only of the target explanation, but also of the associated ideas and language that students might draw upon to make sense of these targets. Priming we thought could prepare teachers for classroom dialogue, to recognize traces of partial understandings in students' talk and to have considered ahead of time how to respond productively as students explore science ideas. In other words, we planned for the tool to expand the range of what novices recognize as student contributions that could be built upon or challenged in particular ways, rather than dismissed as irrelevant. In this way, priming goes beyond, and should precede, mental rehearsals of the day's lesson.

The role of discourse tools in science teaching and learning

While it may seem intuitive to focus on the abilities of the beginning teacher to design and manage activities for students, recent scholarship has emphasized that meaningful learning is a product *not of material activity*, but of *sense-making discourse* aimed at developing conceptual understanding (Mortimer & Scott, 2003). Sense making and scaffolded discussion, calling for particular forms of talk, are "the primary mechanism for promoting deep understanding of complex concepts and robust reasoning" (Michaels, O'Connor, & Resnick, 2008, p. 284). In this view, learning is not accomplished through the transmission of knowledge from person to person, or the passive absorption of ideas from hands-on work, but rather through an ongoing process of comparing one's own understandings with those that are being aired out on the social plane of the classroom (Herrenkohl & Guerra, 1998; O'Connor & Michaels, 1996).

Dialogue in conjunction with material activity also engages learners in the canonical practices of science—that is, "to formulate questions about phenomena that interest [students], to build and critique theories, to collect, analyze and interpret data, to evaluate hypotheses through experimentation, observation, measurement, and to communicate findings" (Rosebery, Warren & Conant, 1992, p. 65). These forms of discourse are rare, even in the classrooms of experienced teachers (Banilower, Smith, Weiss, and Pasley, 2006; Horizon Research International, 2003; Roth & Garnier, 2007; Weiss, Banilower, McMahon, & Smith, 2001). Despite this, we felt that with specially designed tools and other forms of assistance, novices could learn to support important forms of discourse with their students.

We constructed outlines for a set of three discourses to serve as the remaining HLPs. Indentifying specific patterns of conversation and then parsing out the intellectual work necessary to participate in such talk is part of what Grossman et al. (2009) refer to as "decomposing" instructional acts, that is, "breaking down complex practice into its constituent parts for the purposes of teaching and learning" (p. 8). Each of the three discourses included aspects of planning, enactment, and reflection. Each was supported by a tool which explained the purposes of that discourse, that situated it within the larger Science Learning Framework, and that provided a template for a series of teacher-student or student-student exchanges that would ideally accomplish the goals of the overall conversation. These sample exchanges were developed by an analysis of expert teacher conversations from the literature and from our own backgrounds as experienced educators. Each page in the tool containing the sample dialogue also included, in a left hand margin, pre-planning questions for the participants to answer in anticipation of enacting this discourse in simulations held during the methods course or during student teaching (Figure 2 shows a page from the discourse tool: Helping Students Make Sense of Material Activity). In the right hand margins are a parallel series of reflection questions to be answered after they had enacted the discourse with peers or with secondary students.

We recognize that encouraging student discourse in classrooms is not a guarantee that equitable teaching is happening, however we have integrated the following ideas into the tools and the ways that we have talked about instruction with our pre-service teachers:

- Instruction is centered around phenomena that are relevant and apprehensible to young learners, as are the essential questions that guide instruction.
- The accompanying tools and other resources we've developed provide strategies for and examples of hearing a wider range of student voices in the classroom.
- Students' everyday language and experiences are framed as resources to be capitalized on when making instructional decisions.
- The discourses emphasize high expectations for all students and demand teacher attention to those students who may not be participating.

The following sections describe the three discourses in more detail.

Eliciting students' ideas to adapt instruction.

This practice initiates all units of instruction. The goal is to elicit students' understandings of a phenomenon (e.g. a bicycle rusting in the backyard) that is related to an important scientific idea (in this case chemical change or conservation of mass) and then to analyze students' ways of talking about it in order to adapt upcoming instruction. Among the components of this practice are: planning beforehand a rich task that can reveal a broad range of student thinking on the target big idea; eliciting observations from students about a phenomenon of interest to them and encouraging students to offer initial causal hypotheses about the phenomenon (the questions and tasks in this practice emerge from the Big Idea Tool), assisting students in synthesizing what they think they know and what they want/need to know, and after class, analyzing students' contributions to shape instruction. The latter part of the tool supports an analyses of students' 1) everyday language and experiences that can be leveraged to help them participate in scientific discourse related to the target idea, 2) partial understandings, and 3) alternative conceptions. The trends emerging from this analysis are then used to make decisions about how to "work on students' ideas" in subsequent lessons, a practice we reinforce as what all good teachers do.

Pre-thinking:

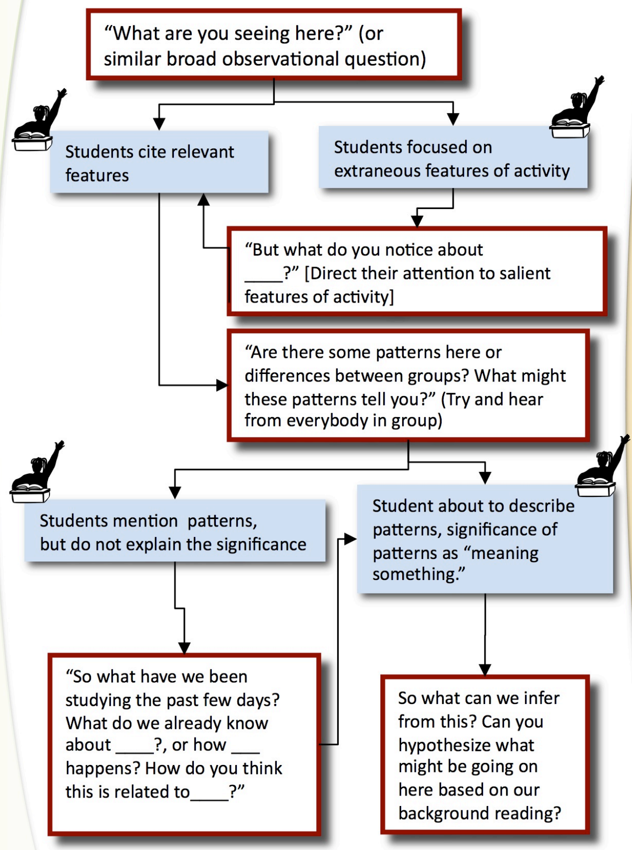
What patterns do you want students to recognize?

What question will you pose to help kids who don't recognize salient patterns?

How will you handle the special academic language demands associated with this activity?

Back-pocket questions: Observations and patterns

When students break into small groups, circulate among them and consider these questions.



Post-reflection:

What did students say about observations and patterns that you did not expect?

How did you respond and how would you respond differently next time?

What evidence do you have that your scaffolding was at least partially successful?

Figure 2. Sample page from discourse tool on "Making sense of material activity"

Helping students make sense of material activity.

The goal of this practice is to combine hands-on work with readings and conversation in order to build content knowledge and to advance students' understanding of a natural phenomenon. This practice is designed to be enacted multiple times in a unit of instruction—repeated cycles of reading or presenting of new ideas, engagement in a hands-on activity, sense-making conversations by students, and using students' new understandings to further instruction. This practice is composed of three parts, the second of which involves a discourse tool.

First, what is judiciously presented to students through teacher-led discussions or media are features of the big idea (in the form of a scientific model) that are not directly observable. In other words, underlying events, processes and entities that would help students understand some aspect of the observable world, but are not "discoverable" through exposure to material activity or data (via experiments, demonstrations, lab activities, etc.). Following this building of background knowledge comes an activity in which students use partial knowledge of the unobservable/theoretical processes to make sense of observations generated from hands-on work or from second hand data. The sense-making discourse takes place during and after this activity. The goals are of this multi-part discourse are to:

- help students understand how the activity relates to a scientific question or idea they have been puzzling over,
- assist students in bridging the observations or data collected during the activity with a larger scientific idea and,
- support the development of students' academic language as a resource for communicating concepts and making sense of scientific ideas within the classroom community.

Following several rounds of hands-on work and sense-making conversations, the teacher re-visits with students their previous hypotheses and partial understandings. The teacher takes stock of students' new ideas and uses this information to design further lessons.

Pressing students for evidence-based explanations.

This conversation usually comes after the teacher has allowed students to create some initial models of the key phenomenon, given them some data collection experiences, and provided them with important written resources to aid their conceptual understanding. This discourse is designed to happen at the end of a unit, but elements of this conversation can also happen any time the teacher is trying to get students to talk about evidence.

The goal of this discourse is to assist students in co-constructing evidence-based explanatory models for the natural phenomenon that have been the focus of the unit. These models depict, in words and drawings, a chain of reasoning linking observations and information from a variety of sources students have had experiences with (first-hand data, second-hand data, information resources, known facts, concepts, laws, etc.) to unobservable events, structures, or processes. The phenomenon being explained could be the focus of a model-based inquiry that students have engaged in over the previous few days (e.g. Why do pulleys help us lift heavy loads?), or a puzzling situation for which students have primarily second hand data (e.g. Why asthma is so prevalent in poor urban communities?).

We typically extend this discourse over at least two class periods. It follows this general pattern: re-orienting students to the possible explanatory models and hypotheses that could have been proposed up to this point, coordinating students' tentative explanations with available evidence, prompting students to talk about the strength of the evidence and the reasoning that links evidence with explanations, writing a final explanation, and having students apply the new explanatory model in contexts beyond those previously discussed.

What Happens When the Core is Put Into Practice

Can high leverage practices be taught to and learned by novices?

Although this testing phase of our research is just beginning, clear patterns are emerging. Our current cohort of seventeen pre-service teachers has been through two quarters of our methods class in which all four HLPs were introduced, modeled by the instructor, and practiced by the teacher candidates themselves. These participants have also completed seven months of student teaching, all as interns in high needs schools.

We sought answers to the question: Can novices appropriate these high-leverage practices with the help of the tools? Participants quickly began to adopt shorthand terms such as "Discourse One" in conversations among themselves and with us as instructors. These terms were used by participants in university classes, on discussion boards, and in practicum de-briefings to signify taken-as-shared pedagogical aims. "Discourse One" in conversations stood in for: "I need to find out what my students know." Member checks of the data confirmed that this shorthand also was used to express the means for achieving teaching objectives—"I need to do this by probing and making public students' thinking about a puzzling natural phenomenon." In line with this focus on discourse, most (but not all) participants began to view classroom activity as opportunities for different kinds of talk, rather than as repeated cycles of "lecture-lab-lecture-lab-test." During their practicum, participants were able to use the discourse tools to create cohesive lessons, although we would classify their initial attempts at conversations with students as "clumsy implementation."

Because eliciting and responding to student thinking is explicitly built into the discourse tools, most participants were able to uncover valuable elements of students' ideas. About a third of participants could also respond meaningfully to their students' ideas in the midst of class conversations, albeit with various degrees of effectiveness. Attending to student thinking in the moment is considered a skill that develops only after significant time in the classroom (see Berliner, 2001; Carter, Cushing, Sabers, Stein & Berliner, 1988). Our findings however and other recent work (Levin, Hammer, & Coffee, 2008) have shown that novices are quite capable of this if given tools and support.

Because participants and methods instructors were using the same tools, and because these tools became boundary objects that spanned learning contexts (university and the field), they served as mechanisms to de-privatize practice, anchoring a common language that could more readily support conversations about student learning. There were even productive outcomes when participants discussed the shortcomings of the tools. Several noted, for example, that in order for their students to have a summary discussion of evidence at the end of a unit, students needed to recall the hands-on activities they had been involved with and document what they had learned from each. As a result, the participants and university instructors co-developed a new genre of tool—public records of student thinking—which was comprised of six different types of display and suggestions for classroom use, each tailored to specific instructional situations that had arisen for participants.

Lampert and Graziani (2009) note how similarly purposed resources, developed at an Italian language learning school, shaped not only individual practice, but the organization's ability to interrogate and adapt instruction.

> We learned that the materials of the school are often the means by which social and intellectual assets are built as they are concrete representations of ambitious teaching and learning. As such, they coordinate instructional activity around a common set of interpretations of students' performance and also a common set of beliefs about how teachers should respond in ways that improve student performance over time…When these assets are used as resources at Italiaidea they have the power to enhance other assets, which in turn positions the school as an organization to support ambitious instruction (p. 499).

At a broader level of analysis we saw that participants could implement the primary features of these meso-level practices, but they tended to abstract from them only a gestalt vision of the interactions between teacher and students. For example, even though they could craft rich tasks to elicit learners' initial ideas about a scientific phenomenon and ask a variety of probing questions, they did not use the differentiated levels of questioning that we had built into the first discourse tool—that is, the strategic succession of question types that demark experts from less accomplished teachers. Each tool/practice then, became essentialized to a degree when used in the field, diminishing young learners' opportunities to participate more fully in productive forms of discourse and knowledge construction.

Part of the explanation for this may be that aspects of the tools or practices themselves were inaccessible, but we also could not overlook the fact that the essence of our core—the conception of teaching as "working on students' ideas"—was largely incommensurable with typical practices our participants encountered in their classrooms (see the following section on cooperating teachers' views of the core). For example, spending time getting to know what partial understandings students have of some scientific phenomenon, or pressing kids to construct evidence-based causal explanations are not often part of standard teaching, nor are these practices supported by most curricula. Thus the dual intellectual burdens placed on these novices was to develop competency in everyday routines like organizing lab work or quieting a class down, while at the same time translating everyday curricula into more ambitious teaching. The latter represents developing a *beginner's form of adaptive expertise* (Bransford, Derry, Berliner, & Hammerness, 2005; Hatano & Inagaki, 1986). Adaptive expertise requires the ability to innovate and adapt flexibly to new situations. Our participants were, on one hand, struggling to decide which practices from the core were appropriate for a given situation (which even under optimal supportive conditions would be challenging to enact) while on the other hand, trying to hybridize these core practices with traditional activities outlined in their curricula or modeled by their cooperating teacher. We cannot be sure whether some of our participants found the core practices unattainable because of their conceptual complexity and the discursive aptitude required, or because they were not able to reconcile the practices with the curricular limitations of their classroom context.

Core as the basis for bridging university and field experiences

When our participants began working in classrooms, their focus on enacting *specific practices* from our core generated a new dynamic between them and their cooperating teachers (CTs). In previous versions of our preparation program, interns were "turned over" to the CTs later in the program and had been only loosely accountable for using strategies learned at the university. But with the expectation that interns were now to be building instruction around Big Ideas and engaging students in specific kinds of sense-making discourse, tensions emerged immediately. Many CTs felt that the requirement for enacting particular practices was usurping their authority to mentor their interns. We had anticipated that each of the core practices could be used with any standard curriculum without having to re-invent it, but that was not how the core was received by either the interns or their CTs. Although we as instructors had met with all the CTs before the practicum and explained the core to them, it was clearly not enough for them to understand our vision or to buy into our aims.

The most chronic tensions arose from the fact that many CTs had no substantive science ideas at all built into their own lessons, something that our interns recognized immediately as undermining much of the teaching they had grown accustomed to in university coursework experiences. The lack of attention to big ideas caused a number of problems as interns and CTs began to co-teach. One was that the science taught was too frequently incorrect, but more importantly to the idea of a core was that without a big idea to hold together a series of lessons, instruction was often reduced to a succession of disconnected activities for students. In addition, without a big idea or at least the overarching puzzling phenomenon, there was nothing for students to explain and no expectation that they would use each day's activities or readings to refine a set of ideas or use these as evidence for a culminating scientific argument.

The core's focus on student thinking—incorporated into practices such as eliciting students' ideas, adapting lessons to students' state of understanding, and pressing them to reason about science ideas rather than memorize vocabulary—was viewed by about half of our CTs as laudable but conceptually unwieldy and too time-consuming. Interns received a number of institutional signals to cover curriculum and to "keep up" with other teachers in their departments. Similar to studies noted elsewhere in the literature, the classroom focus was largely on the teachers' presentation of ideas and skills, not on student thinking.

Not all intern-CT partnerships were rocky. Several cooperating teachers allowed the interns to try to out core strategies within the context of the existing curriculum and, although these early attempts by novices were "clunky," over several weeks some innovative teaching began to unfold. In one case there was an unusual congruency between the curricular visions of the CT and the intern, because the CT had been working with one of us the previous year on the core practices. This CT and the intern started off with shared language and expectations about student learning. This allowed them to experiment weekly on ways to connect the curriculum to students' lived experiences and scaffold students' attempts to develop causal explanations. For example, a unit on the digestive system that was dryly framed by the curriculum as a tour of organs, was transformed into a unit in which the students explored why a young woman with an eating disorder would show similar symptoms of physical distress as a seemingly fit woman who participated in ultra-marathons—a puzzle that engaged students and pressed them to understand body systems in deeper and more connected ways than the curriculum required. Both the planning and de-briefings between the CT and her intern were opportunities to explore science ideas in depth, to hypothesize about instruction, and to frame changes in student thinking in terms of the language of the core.

In a different case of congruence, a cooperating teacher began to realize that her intern's discourse strategies were engaging almost all the students in the classroom in productive talk. This led to the development of mutual trust in the core practices and a further exploration of the tools by the cooperating teacher with her intern. Interestingly, the CT was about to take the National Board for Professional Teaching Standards exams, and noticed that practices the NBPTS was advocating were being attempted by her intern. The CT not only discussed the discourse tools with her intern, she eventually filled out the tools in preparation for the filmed lessons that were submitted as part of her National Boards portfolio, and asked for feedback on these lessons from her intern.

Both cases above are not merely examples of similar visions operating smoothly together, they are *cases of the co-evolution of mentor and intern practice*. These kinds of relationships are critical for carrying the core from the university setting into the field, unfortunately however recent research has characterized most conversations between CTs and their interns as "lost opportunities" in terms of learning (see Valencia, Martin, Place, & Grossman, 2009).

From these outcomes, we are convinced that any theory of action around core practices must include how to work with the cooperating teachers and the local school context. Having specific practices that interns are expected to enact exacerbates the two-world problem that teacher education researchers have documented (see Zeichner, 2010). When core practices are seen as extravagances, too experimental, impediments to someone's teaching schedule, or simply wrong-headed, the novice pays the price. When cooperating teachers support core practices, even if they don't understand them as an organizational framework, the novice appears to make significant strides in their teaching. Not surprisingly, the interns in the two cases mentioned above attempted more forms of ambitious teaching and had more day-to-day successes with student learning than other members of the cohort.

Under Construction: A Final Word About The Beginner's Repertoire

We have argued here that if sets of high-leverage practices for different subjects matter areas could be articulated and taught across early learning-to-teach contexts, the broader teacher education community could collectively refine these practices as well as tools and other resources that support their development. Without an identifiable set of core practices to anchor instruction by both teacher educators and beginning teachers, improvement in instruction will continue to be isolated, individual, and haphazard. Core practices could become the basis for the design of tools (like ours) for novices and for resources such as classroom case studies in video form, along with educative samples of pupils' performances and written work. A set of core practices could support more coherent inquiries into student learning by teacher interns, their cooperating teachers and departmental colleagues—this support would come in the form of shared conceptions and a common language around particular practices. By extension, mentoring of novices during the induction years could be grounded both in conversations about these practices and in how students participate in these practices. A set of core practices could be represented along the spectrum of effective implementation—essentially portrayed as a set of *performance progressions* for teachers to locate their current practice in pedagogical space, envision what the next level of performance might look like, and identify moves and tools needed to take their practice in that direction. These tools, moves, assessments, and institutional commitments form the basis for a science of performance improvement and are already being built into some teacher education programs (Furtak, Thompson, & Windschitl, in press).

We acknowledge the controversial nature of this proposal. There are no ideal forms of practice, but rather there are instructional enactments that assist novices in achieving important teaching and learning goals with more success and consistency than others. Ball and Forzani (2009) remind us that teaching is widely held to be "improvisational, uncertain and impervious to specification" (p. 507) and indeed some of the skills of experts are so tacit and situational that capturing them as pedagogical prescriptions is futile (Polyanyi, 1958). Perhaps the best way to counter the notion that teaching must be individually constructed from experience and address concerns that a focus on core practices might de-skill educators is to produce case studies that demonstrate the range of principled innovation possible by novices who use the frames of HLPs as guidelines rather than scripts. These stories, of course, would need to include documentation of pupil and teacher learning. And for readers who imagine the tools discussed here as an effort to hyper-normalize early practice, we can assure them that our participants' teaching attempts, both at the university and in the field, were varied, imaginative, and uniquely adapted to the needs of their students.

At the end of the day, failure to make hard choices about preparing teachers with important instructional skills will leave us with our current state of affairs—a nationwide collection of preparation programs in which novice teachers' developmental trajectories cannot be supported by clear standards of definable practice or supported by specialized tools, and institutions that are less able to systematically improve their instruction. We recognize too that any proposal for prioritizing instructional practices in our teacher preparation system will be heavily scrutinized, given that no such subset can fully support the development of effective, caring, and reflective practitioners. Our aim here is not to advocate for a new pedagogical orthodoxy, but rather to cultivate responsive mechanisms for the renewal of teacher preparation. As our research group continues to gather data and refine our systems of support, we will gain a clearer picture of the promises and the pitfalls of focusing on high-leverage practices as a way to improve the performance of the next generation of teachers and the evolution of teacher education.

Footnotes

[1]We do not suggest there is a science of *teaching*.

[2] The difficulty our participants experienced in identifying big ideas to teach can be partially but not entirely explained by the literature on subject matter understanding. Beginning science teachers' content knowledge is often superficial (Anderson, Sheldon, & Dubay, 1990; Duschl, 1983; Gallagher, 1991) and poorly integrated (Gess-Newsome & Lederman, 1993). Both the lack of depth and fragmentation likely contributes to the tendency for novice educators to accept topics listed in curricula at face value and teach them uncritically as important science ideas (see Davis, Petish, & Smithey, 2008).

References

AACTE (2010). *The clinical preparation of teachers: A policy brief*. American Association of Colleges for Teacher Education. Washington, DC.

Adams, P. E., & Krockover, G. H. (1997). Beginning science teacher cognition and its origins in the preservice secondary science teacher program. *Journal of Research in Science Teaching*, *34*, 633-653.

Anderson, C., Sheldon, T. & Dubay, J. (1990). The effects of instruction on college non majors' conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching*, 27, 761-776.

Ball, D. & Forzani, F. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education, 60*(5), 497-511.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal for Teacher Education,* 59(5), 389 – 407.

Ball, D. L., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *Elementary School Journal,* 109(5), 458–474.

Banilower, E., Smith, P. S., Weiss, I. R., & Pasley, J. D. (2006). The status of K-12 science teaching in the United States: Results from a national observation survey. In D. Sunal & E. Wright (Eds.) *The impact of the state and national standards on K-12 science teaching*, pp. 83-122. Greenwich, Connecticut: Information Age Publishing.

Berliner, D.C. (1994). Expertise: The wonder of exemplary performances. In J. Mangieri and C.C. Block (Eds.), *Creating powerful thinking in teachers and students: Diverse perspectives* (pp. 161-186). Fort Worth, TX: Harcourt Brace College Publishers.

Berliner, D.C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research, 35*(5), 463-483.

Boyd, D, Grossman, P., Lankford H., Loeb, S., & Wykoff, J. (2008). Teacher preparation and student achievement (NBER Working paper No. W14314). Cambridge, MA: National Bureau of Economic Research.

Bransford, J., Derry, S., Berliner, D., & Hammerness, K. (2005). Theories of learning and their role in teaching. In J. Bransford & L. Darling-Hammond (Eds.) *Preparing teachers for a changing world: What teachers should learn and be able to do*, pp. 40-87. Hoboken NJ: Jossey-Bass.

Bryk, T. (2009). Supporting a science of performance improvement. Phi Delta Kappan, 90(8), 507-600.

Carter, K., Cushing, K., Sabers, D., Stein, P. and Berliner, D. (1988). Expert-novice differences in perceiving and processing visual classroom information. *Journal of Teacher Education*, 39(3), 25-31.

City, E., Elmore, R., Fiarman, S. & Teitel, L. (2009). *Instructional rounds in education: A network approach to improving teaching and learning*. Harvard Education al Press, Cambridge Mass.

Clift, R. T., & Brady, P. (2005). Research on methods courses and field experiences. In M. Cochran-Smith & K. Zeichner
(Eds.), *Studying teacher education* (pp. 309–424). Mahwah, NJ: Erlbaum.

Cobb, P., Zhao, Q. & Dean, C. (2009). Conducting Design Experiments to Support Teachers' Learning: A Reflection From the Field, *Journal of the Learning Sciences,18*(2),165-199.

Cohen, D. (forthcoming). *Teaching: Practice and its predicaments*. Cambridge, MA: Harvard University Press.

Cohen, D. (2007). Problems in educational policy and research. In S. H. Fuhrman, D. K. Cohen, & F. Mosher (Eds.), *The state of education policy and research* (pp. 349-371). Mahwah, NJ: Lawrence Erlbaum.

Darling-Hammond, L. (2010). America's commitment to equity will determine our future. *Phi Delta Kappan, 91*(4), 8-14.

Darling-Hammond, L. (Ed.). (2000). *Studies of excellence in teacher education, (3 volumes).* Washington, DC: American Association of Colleges for Teacher Education.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*(4), 607-651.

Deussen, T., Coskie, T., Robinson, L., & Autio, E. (2007). *"Coach" can mean many things: Five categories of literacy coaches in Reading First* (Issues & Answers Report, REL 2007–No. 005). Retrieved July 19, 2008, from http://ies.ed.gov/ncee/edlabs.

Duschl, R. (1983). The elementary level science methods course: Breeding ground of an apprehension toward science? *Journal of Research in Science Teaching*, 20, 745-754.

Elmore, R. (2005, February). *Our best ideas about instructional practice do not operate at scale*. Presentation given at NSF K-12 Math, Science, and Technology curriculum Developers Conference. Washington DC. Feb. 27th.

Fennema, E., Franke, M. L., Carpenter, T. P., & Carey, D. A. (1993). Using children's mathematical knowledge in instruction. *American Educational Research Journal,* 30(3), 555–583.

Franke, M. L., & Chan, A. (2007, April). *Learning about and from focusing on routines of practice.* Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Freese, A. R. (2006). Reframing one's teaching: Discovering our teacher selves through reflection and inquiry. *Teaching and Teacher Education*, *22*, 100-119.

Furtak, E., Thompson, J. & Windschitl, M. (forthcoming) Learning Progressions To Support Teacher Development. In A. Gotwals & A. Alonzo (Eds.) Learning Progressions in Science Education.

Gallagher, J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, 75, 121 133.

Gess-Newsome, J. & Lederman, N. (1993). Pre-service biology teachers' knowledge structures as a function of professional teacher education: A year-long assessment. *Science Education*, 77, (1), 25-46.

Grossman, P., Compton, C., Igra, D., Ronfelt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record, 111*(9).

Grossman, P., & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. *American Educational Research Journal,* 45(1), 184–205.

Hammerness, K., Darling-Hammond, L., and Shulman, L. (2002, April 10-14). Towards expert thinking: How curriculum case-writing prompts the development of theory-based professional knowledge in student-teachers. *Teaching Education (13*)2, 219-225.

Hammerness, K., Darling-Hammond, L., & Bransford, J. (2005). How teachers learn and develop. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world* (pp. 358-389). San Francisco: Jossey-Bass.

Hatano, G. & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.). *Child development and education*, pp. 262-272. W.H. Freeman & Co: New York NY.

Hatch, T., & Grossman, P. (2009). Learning to look beyond the boundaries of representation: Using technology to examine teaching (Overview for a digital exhibition: Learning from the practice of teaching). *Journal of Teacher Education. 60*(1), 70-85.

Herrenkohl, L. R., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade, Cognition and Instruction, 16, 433-475.

Hiebert, J., Gallimore, R., & Stigler, J. W. (2002). A knowledge base for the teaching profession: What would it look like and how can we get one? *Educational Researcher,* 31(5), 3–15.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, 42, 371-406.

Horizon Research International. (2003). *Special tabulations of the 2000-2001 LSC teacher questionnaire and classroom observation data.* Chapel Hill, NC: Horizon Research.

Jackson, P. (1986). *The practice of teaching*. New York: Teachers College Press.

Lampert, M., & Graziani, F. (2009). Instructional activities as a tool for teachers' and teacher educators' learning. *Elementary School Journal,* 109(5), 491–509.

Lee, C. (2007). *The role of culture in academic literacies: Conducting our blooming in the midst of the whirlwind.* New York: Teachers College Press.

Levine, A. (2006). *Educating School Teachers*. Washington DC: Education Schools Project. Retrieved July 10, 2009 from http://www.edschools.org/teacher_report_releaase.htm.

Levin, D., Hammer, D., & Coffee, J. (2008). Novice Teachers' Attention to Student Thinking. Journal of Teacher Education, Vol. 60, No. 2, 142-154.

Little, J.W. (1990). The persistence of privacy: Autonomy and initiative in teachers' professional relations. *Teachers College Record, 91*(4), 509-536.

Louisiana Board of Regents. (2008). *Regents study shows teacher certification matters*. Baton

Rouge, LA.

Michaels, S., O'Connor, C., & Resnick, L. (2008). Reasoned Participation: Accountable Talk in the Classroom and in Civic Life. Studies in Philosophy and Education. 27 (4): 283-297. Read more: http://www.clarku.edu/academiccatalog/facultybio.cfm?id=15#ixzz0KPZQlrC9&C

Mortimer, E. & Scott, P. (2003). *Meaning making in secondary science classrooms. Philadelphia*: Open University Press.

Murray, F. (1989). Explanation in education. In M. Reynolds (Ed.) *Knowledge base for the beginning teacher* (pp. 1-12). New York: Pergamon.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council (2005). *America's Lab Report: Investigations in High School Science. Committee on High School Laboratories*: Role and Vision. Susan R. Singer, Amanda L. Hilton, and Heidi A. Schweingruber, Eds. Board on Science Education. Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academies Press.

National Research Council (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. Committee on Science Learning, Kindergarten Through Eighth Grade*. R. A. Duschl, H. A. Schweingruber, and A. W. Shouse (Eds.). Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Newmann, F., & Associates. (1996). *Authentic achievement: Restructuring schools for intellectual quality.* San Francisco: Jossey-Bass.

Nolen, S. B., Ward, C. J., Horn, I. S., Childers, S., Campbell, S., & Mahna, K. (2009). Motivation in pre-service teachers: The development of utility filters. In M. Wosnitza, S. A. Karabenick, A. Efklides & P. Nenniger (Eds.). *Contemporary Motivation Research: From Global to Local Perspectives*. Ashland, OH: Hogrefe & Huber.

O'Connor, M. C., & Michaels, S. (1996). Shifting participant frameworks: Orchestrating thinking practices in group discussion. In D. Hicks (Ed.), *Child discourse and social learning* (pp. 63–102). Cambridge: Cambridge University Press.

Penuel, W. & Gallagher, L. (2009). Preparing teachers to design instruction for deep understanding in middle school earth science. *Journal of the Learning Sciences, 18*(4), 461-508.

Polyanyi, M. (1958). *Personal knowledge: Towards a post-critical philosophy*. London: Routledge.

Rand. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*.
Santa Monica, CA.

Raudenbush, S. (2008). Advancing educational policy by advancing research on instruction. *American Educational Research Journal, 45*, 206-230.

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences,* 2(1), 61-94.

Roth, K. & Garnier, H. (2007). What science teaching looks like: An international perspective. *Educational Leadership*, 64(4), 16-23.

Smith, J., Lee, V., & Newmann, F. (2001). *Instruction and achievement in Chicago elementary schools.* Chicago: Consortium on Chicago School Research, Chicago Annenberg Research Project.

Thompson, J. Windschitl, M. & Braaten, M. (April 2009). How Pedagogical Reasoning and Ambitious Practice Develops Across "Learning to Teach" Contexts. *Annual conference of the National Association of Research in Science Teaching*. Anaheim, CA.

US Department of Education (2008). *The final report of the National Mathematics Advisory Panel*. Washington DC.

Valencia, S., Martin, S., Place, N., & Grossman, P. (2009). Complex interactions in student teaching. *Journal of Teacher Education, 60*(3), 304-322.

Warren, B., & Rosebery, A. S. (1996). "This question is just too easy!" Students' perspectives on accountability in science. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 97–125). Mahwah, NJ: Lawrence Erlbaum Associates.

Weiss, I. R., Banilower, E. R., McMahon, K. C., and Smith, P. S. (2001). *Report of the 2000 National Survey of science and mathematics education*. Horizon Research Inc. Available at www.horizon-research.com.

Windschitl, M. Thompson, J., & Braaten, M. (forthcoming) Ambitious Pedagogy by Novice Teachers? Who Benefits From Tool-Supported Collaborative Inquiry into Practice and Why. *Teachers College Record.*

Yackel, E., & Cobb, P. (1996) Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education, 27*(4), 458-477.

Zeichner, K. (2010). Re-thinking connections between campus courses and field experiences in college and university-based teacher education. *Journal of Teacher Education, 61*(1-2), 89-99.

Zeichner, K. and Tabachnick, R. (1981). Are the effects of university teacher education 'washed out' by school experience?' *Phi Delta Kappan, 32 (*3), -11.