Supporting Growth of Pedagogical Content Knowledge in Science

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Our program of research has investigated the development of teachers' pedagogical content knowledge (PCK) in science as a result of their participation in professional development intentionally designed to strengthen PCK. This chapter traces the co-evolution of our research, our professional development model, our notions of PCK, and our understanding of how best to support growth of teachers' PCK.

Broadly, we view PCK as the intersection of knowledge about content and teaching—that is, knowledge for teaching topic-specific content. Our early conceptions of PCK were rooted in the core elements introduced in Shulman's original formulation—*teachers' knowledge of learners,* such as understanding students' thinking and reasoning, and what makes a specific topic easy or difficult for learners; and *teachers' knowledge of teaching,* such as ways of formulating, sequencing, and representing the subject matter to make it comprehensible to learners (Shulman, 1986, 1987). While the PCK Summit, as presented in this volume, highlighted the many components comprising PCK, we have focused our studies on teachers' abilities to (a) organize instruction around an accurate, precise, and coherent set of interrelated conceptual learning goals; (b) anticipate, elicit, interpret, and address particular challenges the content poses for their students; and (c) sequence and represent that content during instruction in a way that advances their students' understanding. Teachers utilize or "enact" this professional knowledge while actively engaged in content-specific teaching and while planning, analyzing student work, and reflecting on their instruction.

The historical backdrop of the last two decades in the U.S. has played a significant role in shaping our work. With consistently low student achievement scores, an underprepared teaching force, implementation of rigorous standards, and a dearth of high-quality professional development opportunities for teachers, our nation has been in dire need of a solution. The landmark report, *Taking Science to School: Learning and Teaching Science in Grades K–8*, produced by the National Research Council in 2007 called for a comprehensive professional development program that is "conceived of, designed, and implemented as a coordinated system," to support students' attainment of high standards (Duschl, et al., 2007, p. 347).

With support from the National Science Foundation (NSF), the U.S. Department of Education's Institute of Education Sciences (IES), the Stuart Foundation, and the W. Clement and Jessie V. Stone Foundation, a team of science educators from WestEd and researchers from Heller Research Associates and the University of California, Berkeley responded to this challenge to improve student achievement by developing and studying

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the Making Sense of SCIENCE (MSS) model for teacher learning. The MSS model builds on the work of Carne Barnett-Clarke and her mathematics colleagues at WestEd (Barnett-Clarke & Ramirez, 2004), and utilizes a case-based approach to teacher education, informed by the work of Lee and Judy Shulman.

At present, MSS resources have grown to nearly a dozen courses for teacher learning that cover core topics in earth, life, and physical science (e.g., matter, organisms, earth systems) for K–12 teachers. Some courses have been co-published and widely disseminated by the National Science Teachers Association. Since 1998, more than 20 states across the U.S. have invested in training science educators to lead MSS courses with thousands of teachers, providing tens of thousands of hours of professional development, and reaching hundreds of thousands of students.

The MSS theory of action posits that teacher professional development improves student achievement through intermediate effects on teachers' content knowledge (CK) in science and their pedagogical content knowledge (PCK), as shown in Figure 1. We have tested different links in this causal chain by examining the impact of our professional development courses on all of these outcomes. In increasingly rigorous quasi-experimental and experimental studies, we have found that MSS teachers and their students consistently show significant gains compared to control groups on measures of science content knowledge, with non-native English speakers and low-performing students making the greatest gains (Heller, Daehler, & Shinohara, 2003; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012).

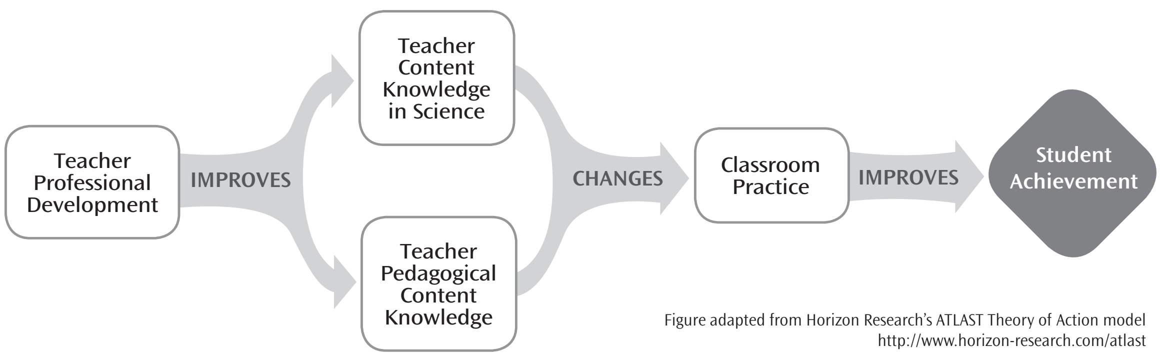

Figure adapted from Horizon Research's ATLAST Theory of Action model
http://www.horizon-research.com/atlast

Figure 1. *Making Sense of SCIENCE theory of action.*

PCK Journey

In this chapter, we detail the interrelated co-evolution of our professional development model, our research, and our understanding about how to support the development of PCK. Over the past two decades our PD model has gone through three major research-based iterations that reflect shifts in our understanding about how to support PCK development: (a) PCK Cases, (b) the Learning Science for Teaching series, and (c) Making Sense of SCIENCE courses.

Phase I: PCK Cases

The roots of our current MSS model extend back to the late 1990s, when the approach began as a collection of teacher-written cases about teaching physical science topics (e.g., electric circuits, sinking and floating, light). Each PCK case described a slice of teaching and a content-based instructional dilemma—for example, the challenge of finding an accurate and accessible model to help students understand the flow of electrical current in a circuit. The cases highlighted common areas of student difficulty, featured classroom artifacts, and served as a basis for engaging teachers in in-depth discussions. Wall charts like the sample shown in Figure 2 were used to document the group's conversation during facilitated whole-group discussions about the cases.

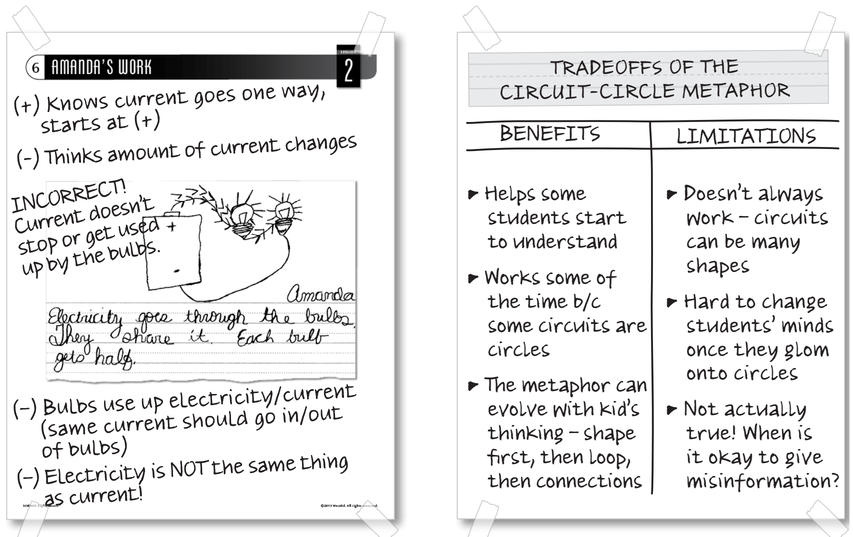

Figure 2. *Sample charts showing how teachers interpret student work in a PCK case and identify the tradeoffs of a common metaphor used in instruction.*

One of our early studies (Heller, Daehler, & Kaskowitz, 2004) demonstrated that these case discussions supported growth in PCK. This study followed 12 teachers and tracked how their CK and PCK changed over time as they participated in six case discussions over several months. During in-depth interviews, conducted before and after teachers' participation, teachers were shown a student assessment task, for example a picture of two bulbs connected in a parallel circuit, and were asked, "How would you go about helping your students understand what happens when one bulb is unscrewed?" and "What do you think would be hard about this task for students?" Later, teachers were shown a sample incorrect student response (see Figure 3) and were asked to analyze the student work and describe the instructional approach they would take with this student. The interviews elicited rich information about (a) teachers' own science understandings, (b) what they anticipated as student difficulties, (c) how they would help students understand specific science content, for example, how electrical current flows in a parallel circuit, (d) their interpretation of a sample student response, and (e) how the teacher would go about helping that particular student develop a stronger understanding of a specific concept.

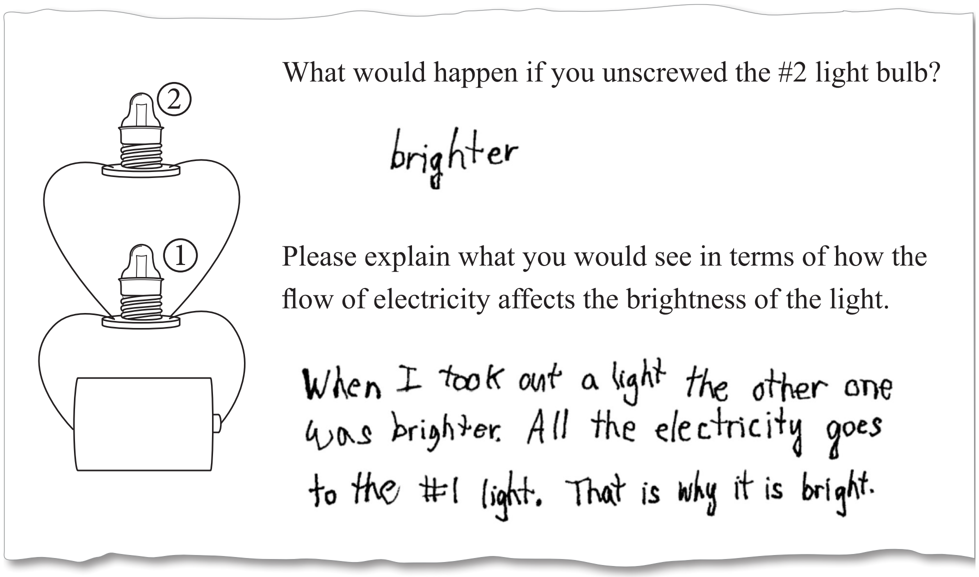

Figure 3. *Excerpt from PCK interview prompt with sample student response.*

After participating in six case discussions, teachers showed gains in both their CK and PCK, as measured by content tests and interviews. During the pre interview, teachers typically named one general challenge without elaboration, such as, "parallel circuits are hard." During the post interviews, however, teachers had a more nuanced and accurate understanding of the science, which allowed them to anticipate multiple, detailed student difficulties related to learning about circuits, for example:

> Resistance is very hard . . . , the fact that . . . the resistance of light bulbs in a series circuit causes the entire circuit to use less electricity, so it reduces flow. And how on earth could that be true if, in a parallel circuit, it's brighter, there's more flow in it. . . . That's just very, very hard to get across. Also that the number of bulbs and how they are arranged in the circuit affects the way the battery kicks out juice, and the fact that you've got two batteries, it's different than having one. . . . Light bulbs are tricky too. Because . . . the kids don't really think of them as part of the circuit unless you explicitly teach that or have them dissect a bulb so that they can actually look at the wire and the two places the wire touches and forms part of the circuit.

Many teachers demonstrated increased complexity and accuracy in their analysis of student work. During the post interviews it was more common for teachers to speculate about what might have led to the student's incorrect answer than during the pre interview, as shown in the following response.

> I'm wondering if this student [work shown in Figure 3], if he is incorrect, he's transferring knowledge from a series circuit to a parallel circuit. But he's transferring the knowledge from a series circuit, not if you take a bulb out, but instead of having two bulbs being lit up, versus just one bulb. That's what it looks like to me.

Through participating in PCK case discussions, many teachers also became better able to make explicit links between specific student difficulties and proposed instructional interventions, and demonstrate increased complexity in their descriptions of teaching strategies. For example, teachers emphasized having students explicitly consider and trace different pathways for the current in a circuit.

> I would again ask them to conceptualize where the electricity is flowing. They know that electricity originates in the D cell, with the chemical reaction, and that it's trying to get from the negative back to the positive side. So if we unscrew Bulb 2, it no longer has a route through Bulb 2, but it still does have an alternative route through Bulb 1. So I'd want them to think about that. Think about when Bulb 2 was screwed in, it had two routes, and therefore it was taking both routes. But when Bulb 2 was unscrewed, it only has one route.

Our rubric for analyzing these teacher interviews was informed by prior work done in the context of Carne Barnett's Math Case Methods project (Barnett, 1991; Ball, 1988, 1990, 1991; Gordon & Heller, 1995). Gordon and Heller examined whether teachers who participated in math case discussions came to reason differently about the mathematics content and teaching they had encountered in those discussions. This pedagogical reasoning was conceptualized metaphorically as the act of traversing a complex, interconnected "web" of mathematical information and meanings related to a particular component of content being taught, in combination with a set of considerations about the teaching and learning of that content.

Gordon and Heller's analysis of PCK focused on teachers' responses to the interview question, "Could you explain how you might go about helping students understand problems like '2.4 x 0.5' (on post, '4.8 x 0.5')?" This revealed that some features of pedagogical knowledge for teaching content can be assessed along two major dimensions—the *semantic complexity* of the content described by the teacher and the *pedagogical complexity* of the teacher's thinking. Semantic complexity can be thought of as the richness of the mathematical or scientific meanings incorporated in the teacher's thinking about teaching and learning (Leinhardt, 1985). Pedagogical complexity can be thought of as the extent to which the teacher evidences careful and explicit analytical thinking in order to form judgments about instructional approaches, materials, and procedures. From analyses of interviews with Math Case Methods participants, three levels of pedagogical complexity emerged, each of which includes the following three dimensions:

- Focus on Students—description of what students do, know, think, understand, or find difficult, with respect to particular aspects of content
- Emphasis on Making Meaning—descriptions and explanations, representations, or strategies for illustrating meanings of both quantities and the multiplication process
- Critical Analysis of Practice—analysis of multiple instructional practices, materials, and processes, along with attention to the relationship between features of instruction and particular purposes with respect to student learning and thinking

This model of pedagogical reasoning was used to characterize how 12 new and continuing participants in the Math Case Methods project reasoned about the instructional problem posed during the interview. Analysis revealed that none of the six new participants began in, or moved to, the strongest levels of pedagogical or semantic complexity, even when their mathematical content knowledge scores were high. In contrast, all six of the continuing participants were at the strongest levels of pedagogical and semantic complexity by the end of the school year, and all had high mathematical content knowledge scores. Although based on a limited sample of teachers, these patterns suggest that PCK develops over time and more sophisticated knowledge about teaching seems to be associated with strong content knowledge. At the same time, strong content knowledge by itself is not sufficient for developing strong PCK, which means other factors must support the growth of this kind of specialized knowledge for teaching.

Building on this math work, our analysis of teachers' involvement in PCK case discussions in science reinforced several hunches about what supports growth in teacher knowledge. When audio records of case discussions were closely examined, we found that teachers who had weaker CK struggled to identify common misconceptions in the student work, often because they shared the same incorrect ideas. Weaknesses in teachers' CK also limited their abilities to analyze the tradeoffs between various instructional decisions, leading to statements about general approaches to teaching (e.g., direct instruction versus inquiry) rather than rich, content-specific conversations that sharpened and refined their pedagogical reasoning. Over time, it became apparent that significant deficits in teachers' own science CK impeded their ability to strengthen their PCK (Daehler & Shinohara, 2001). In summary, we came to understand that teacher CK is necessary for developing PCK, but not sufficient on its own; teachers' own CK is inextricably interrelated with their knowledge about how to teach that content; and weak content knowledge inhibits teachers' engagement in PCK-rich discussions. These findings signaled an opportunity to modify our professional development model by strengthening teachers' CK to support further growth in PCK.

Phase II: Learning Science for Teaching (LSFT) Series

In this second phase, we made several major revisions to our PD model. First, we moved from a collection of cases to a series of eight 3-hour sessions that were carefully sequenced to cover core science concepts related to a given topic (e.g., electric circuits), along with a focus on common misconceptions associated with that same topic. Second, to better prepare teachers for more fruitful case discussions we front-loaded the content by starting each session with a 70-minute science investigation. In contrast to most hands-on activities in professional development, which is designed to help teachers implement a curriculum by guiding teachers through the student activities, LSFT focused on adult-level investigations in which teachers solidified their own understandings of core science concepts.

During science investigation, teachers worked in small groups to conduct hands-on investigations, and engaged in whole-group discussions to make sense of the science. For example, in the first session of electric circuits, groups were provided with a battery, a bulb, and a wire, and challenged to find as many ways as possible to make the bulb light. Based on this experience, groups developed their own working definition of a "complete circuit" and then used it to make predictions about other circuits. A facilitated whole-group discussion followed in which teachers shared circuits they built that lit, did not light, and surprised them. They looked for patterns in their data, and summarized what this helped them understand about circuits. Next, teachers regrouped the data according to complete and incomplete circuits, which predictably led them to discover a tricky aspect of the science: some complete circuits do not result in a lit bulb. To solidify this important understanding, teachers were prompted to describe the relationship between complete, incomplete, lit, and unlit circuits, through drawings, writing, and verbal discussion (Shinohara & Daehler, 2008).

In 2007, we undertook a large-scale research project funded by NSF that included an efficacy study of the newly redesigned LSFT professional development. The study was conducted over a two-year period, in eight sites across six states in the U.S., involving 49 districts, more than 260 elementary teachers, and nearly 7,000 students, largely from underserved populations. This randomized, controlled trial compared the differential effects of three related but systematically varied interventions, including: a *Teaching Cases* course with discussions of pre-structured written cases of classroom practice (Barnett-Clarke & Ramirez, 2004; Daehler & Shinohara, 2001); a *Looking at Student Work* course involving analysis of teachers' own student work in conjunction with concurrent teaching (Little, 2004; Little, Gearhart, Curry, & Kafka, 2003); and a *Metacognitive Analysis* course with teachers engaging in metacognitive reflection on their own learning experiences (Mundry & Stiles, 2009; White, Frederiksen, & Collins, 2009). Each intervention consisted of 24 hours of contact time, divided into eight 3-hour sessions, and all three included an identical science component that incorporated hands-on investigations, sense-making discussions, and readings. However, the PCK components of each course were varied to test different approaches to focusing on teaching and learner thinking.

Conducting research at this scale presented new challenges, one being the need for a cost-effective means of assessing PCK with hundreds of teachers. Our solution was to develop written, constructed-response items, using questions similar to our PCK interviews. The written PCK items asked teachers to analyze samples of student work, interpret strengths and weaknesses in the students' understanding of electric circuits, and describe instructional strategies for addressing those difficulties. The coding scheme for analyzing teachers' responses focused on recording specific science learning goals teachers said they would target, and recording the instructional representations and activities they mentioned to help students make sense of phenomena.

This study provided strong evidence of efficacy for all three interventions in that each intervention produced significant increases in teacher and student outcomes. Results of HLM analyses showed all three interventions caused sizable gains in teacher CK related to electric circuits, and these increases were significantly greater than control group teachers ($ES = 1.8–1.9$, $p < .001$). In addition, students of these teachers outperformed students of control teachers by more than 40 percent ($ES = .36$), with English learners making the greatest gains ($ES = 0.72–0.76$). HLM analyses also showed the Teaching Cases and Looking at Student Work courses raised teachers' PCK posttest scores significantly when compared with scores of control teachers ($ES = 0.9$ and 0.8, respectively), whereas the Metacognitive Analysis course did not increase PCK (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012). This study confirms that teacher PCK can be strengthened through professional development focused on science content, student thinking, and analysis of practice, in ways that benefit student achievement.

Furthermore, this LSFT study provided an opportunity to determine whether the impact on teacher CK solely accounted for the impact on student achievement, or whether other teacher outcomes might be partially responsible. This question has important policy implications, because if teacher CK solely accounts for student outcomes, this would support decisions to strengthen *only* teachers' CK in science as a means of producing student learning gains. To test this, we compared the results using an HLM model that included teacher content knowledge (and a set of relevant student and teacher covariates), to a model that had both teacher content knowledge and the intervention type (i.e., Teaching Cases). These models were found to be significantly different, and all three interventions had significant positive effects, which indicated expected student gains *beyond those gains due to the teachers' content knowledge*. We concluded that each of the three teacher interventions did something to improve student test scores beyond that of merely improving teachers' CK—something that could well be strengthening teacher PCK. This evidence of professional development impact on teacher pedagogical knowledge reinforced our efforts to understand and measure this knowledge.

These findings led us to ask, "What changes in teacher PCK may have contributed to increases in student science achievement?" To address this question, we analyzed teachers' responses to PCK questions according to several dimensions, including *conceptual learning goals* and *engaging students in meaning making* (see Table 1). The interventions that most strongly led to teachers mentioning at least one specific conceptual learning goal for their students were Looking at Student Work (78 percent of teachers) and Teaching Cases (70 percent of teachers), followed by 62 percent of Metacognitive Analysis teachers. These proportions were approximately double those of the control teachers.

Table 1. *Percent of Teachers Giving Each Category of Response to Written Pedagogical Content Knowledge Question, by Experimental Condition.*

Response to item, "What might the teacher do next to move this student toward further understanding of electric circuits?"	Teaching Cases	Looking at Student Work	Meta-cognitive Analysis	Control
n	67	60	53	69
Mention any conceptual learning goal	70.1	78.3	62.3	36.2
Mention more than one conceptual learning goal	19.4	25.0	18.9	7.2
Teacher has students do hands-on activity only	10.4	8.3	13.2	39.1
Teacher has students do hands-on activity and a making-meaning activity	29.9	13.3	17.0	10.1
At least one strategy involving making meaning	47.8	26.7	22.6	15.9
More than one strategy involving making meaning	14.9	6.7	5.7	4.3

Furthermore, nearly 40 percent of control teachers described having a student only do hands-on work with bulbs, batteries, and wires (for example, "I would have them build it."), with no reference to strategies for helping students make sense of what they observed, whereas fewer than 14 percent of any intervention-group teachers did so. In contrast, the largest proportion—30 percent—of Teaching Cases teachers referred explicitly to strategies for helping students make sense of what they observed (such as by tracing electrical current through the circuit, or creating a T-chart to compare drawings of circuits that did and did not light the bulb) as compared with 10 percent of control teachers. Teaching Cases produced the highest proportion of teachers who mentioned at least one way of engaging students in making meaning, close to 50 percent, versus only 16 percent of control teachers.

In summary, data from the experimental study established that (a) two of the three interventions (Teaching Cases and Looking at Student Work) improved teacher PCK, (b) all three interventions improved student test scores by doing more than merely improving teachers' content knowledge—something that could well be strengthening PCK, and (c) the Teaching Cases course was especially effective at increasing teachers' explicit focus on conceptual learning goals for students, references to engaging students in active roles as learners, and describing strategies for helping students make sense of key science ideas. The courses that most improved both teacher PCK and teacher and student test scores emphasized science content situated in activities and scenarios involving student curricula and instruction, in combination with analysis of student work and classroom pedagogical practice. Based on these findings, policy makers should invest in professional development that emphasizes analysis of student learning, pedagogy, and content, rather than focusing on general pedagogy or purely on content.

Phase III: Making Sense of SCIENCE

Findings from the LSFT study have shaped our current professional development model—Making Sense of SCIENCE. Currently, we think about improving student achievement through a cascade of influences beginning with teacher professional development that is rich in talk about scientific meanings, and focused on student thinking and critical analysis of practice. The current MSS model utilizes the same two core components as our LSFT teaching cases model (science investigations and teaching cases) while adding greater opportunity for teachers to reflect on what they learn during the professional development and to make connections to their own students and classrooms. Furthermore, in response to a nationwide push for science teachers to explicitly support disciplinary reading, writing, and discourse for all students, and to help teachers meet the growing need to support English learners in their classrooms, each MSS course was designed with a specific literacy focus. In addition, in order to fit the implementation needs for a summer institute, the MSS model was redesigned into five days (30 hours of learning) with four main components:

- *Science Investigations*—hands-on collaborative activities engage teachers in foundational science content and practices that are related to the accompanying teaching cases.
- *Teaching Investigations*—case discussions engage teachers in examining student thinking and analysis of detailed instructional scenarios. The materials, written by classroom teachers, contain student work, student/teacher dialogue, context information, and discussions of teacher thinking and behavior.
- *Literacy Investigations*—reading/writing/discourse activities intended to help teachers how to more effectively support students' development of science literacy skills, help students make sense of the science, communicate in science-specific ways, and develop their academic language proficiency.
- *Classroom connections*—opportunities for teachers to read about, reflect on, and discuss key science and literacy concepts and consider how these concepts pertain to their own work with students.

Given that the LSFT study showed different benefits in PCK for the Teaching Cases and Looking at Student Work interventions, we decided to combine both approaches in the current MSS model. During the five-day core course teachers discuss teaching cases, then they meet in professional learning communities for five additional 2-hour sessions during the school year, to (a) examine student work from their own classrooms, (b) evaluate assessment tasks that elicit student understanding, (c) examine classroom artifacts for evidence of student understanding, and (d) plan instructional "next steps" to address particular learning gaps. This school-year component is supported by detailed protocols for teacher-led meetings, as well as a task bank of topic-specific student assessments, lists of learning objectives and common yet incorrect ideas, and sample sets of student work.

Each MSS course comes with a *teacher book* that presents all the materials teachers need to participate, including teaching cases, handouts, and session reviews that summarize the key concepts and outcomes and feature illustrations of common but incorrect ways students think about related concepts. To support scale-up and broad use, each MSS course is also accompanied by a *facilitator guide* that provides detailed yet flexible procedures, in-depth background information, guiding questions and charts for each whole-group discussion, and other tips for leading successful professional development.

While we continue to have a myriad of questions about how best to support the growth of teacher PCK, when we reflect on what we know from our research and development work over the years, and compare our work with that of colleagues at the 2012 PCK Summit, we can identify key ingredients that we believe are part of the "secret sauce" that contribute to growth in teacher PCK. These include:

- *Intertwine science learning with science teaching.* For example, in MSS courses although the science activities are designed for adults, the content is tightly coupled to the science featured in each accompanying teaching case, such that teachers deepen their own understanding of the science in the context of thinking about kids' ideas and classroom experiences. In addition, by using teaching cases that feature pedagogical-content dilemmas, teachers have the opportunity to examine instructional decisions related to teaching core science concepts, including analyzing a variety of metaphors, models, and other representations to help make the concepts comprehensible to students (and themselves), thus reinforcing their science understandings. In addition, after engaging in science investigations, teachers in MSS courses are asked to be metacognitive about what supported and hindered their own learning, as well as what implications their own experiences might have for teaching their own students. In this way, the science and science teaching are always tightly coupled.
- *Provide a high-quality curriculum for teacher learning that models exemplary instruction for science learning*. When engaged in MSS science investigations teachers experience top-notch curricular materials that showcase effective, research-based practices for science learning. This includes the use of a variety of representations to keep ideas "on the table" as objects of and for thought (e.g., graphs, images, diagrams) (Wong, 2009), as well as multi-modal learning opportunities (e.g., reading, writing, discourse, individual, small group, whole group) and a focus on practicing scientific practices (e.g., asking questions, developing explanations, engaging in scientific argumentation).

- *Push for deep conceptual understanding of both the science and science teaching.* MSS courses have been accused of "going for the jugular." This is perhaps because the course development process begins by identifying vexing aspects of the science related to a given topic and then designing learning opportunities that push teachers to examine these tricky issues first-hand. This means teachers often experience cognitive dissonance when they face their own conceptual limitations. Nevertheless, because teachers are immersed in a deep level of thinking about genuinely tough concepts, they often end up with a more relaxed stance about not understanding and come to trust that learning is a process. Through their own experiences they learn the value of raising the rigor in their own classrooms in ways that result in students' developing deeper understandings of science.
- *Leverage collaborative sense-making.* MSS courses are based on a belief that teachers can learn challenging science by working together to make sense of their own experiences and deeply explore their own understandings/misunderstandings. Toward this end, approximately 50% of the learning involves teachers working in small groups, so their thinking happens in the context of other teachers. When working in groups of three, teachers examine data and classroom artifacts in ways that value a variety of viewpoints. As teachers share their own knowledge and experiences, they gain new insights and challenge each other's interpretations, which leads teachers to appropriate each other's ideas.
- *Foster a community of professionals.* Participants in MSS courses frequently comment on the ways in which teachers are treated with utmost respect and supported as they engage in peer-to-peer conversations and rigorous discourse. It is key that teachers hold the locus of authority in their own learning and develop an identity as life long learners who are part of a professional community.

Current and Future Directions

We are currently engaged in examining aspects of teachers' instructional strategies and classroom discourse, to help us understand the processes by which the teachers' professional development experience might influence student achievement. Building on our prior work, and as an outgrowth of conversations with colleagues during the PCK Summit, we will characterize teachers' *enacted PCK* by analyzing the accuracy of the science content communicated by the teachers, the ways teachers elicit students' science ideas during instruction, and the opportunities teachers give students to make sense of science ideas and to read, write, and talk in science-specific ways.

While existing research now confirms teacher PCK (and student achievement in science) can be strengthened through targeted professional development, many unanswered questions remain about how best to do this. For example, What features of the professional learning experience are essential? Are there more efficient or effective way of developing teacher PCK? What happens if video cases are used instead of written narrative cases? What are cost-effective ways of assessing PCK? Will teachers need to engage in professional development for every topic they teach to develop the specialized PCK they need, or do some elements of PCK transfer across content areas? What supports are needed and what barriers exist to scaling? We look forward to the interesting research and development work required to begin addressing these questions. We also look forward to the ongoing collaborations and the collegial conversations that enhance this work, such as that made possible by the PCK Summit of 2012.

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