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Science Geared to How Students Learn

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WestEd's Understanding Science project enhances the knowledge and skills of elementary and middle school teachers, with a particular focus on improving instruction for English learners and those with low literacy skills. Research has shown that the project contributes to improving both teacher knowledge and student achievement in science.

Over the past two years, the Understanding Science project conducted nine Leadership Academies across the country to prepare district and regional service staff and teacher leaders to provide professional development for some 800 elementary and middle school teachers. Each set of professional development sessions focused on a specific science topic and grade span, such as electric circuits for grades 3–5, force and motion for grades 6–8, and matter and chemical change for grades 6–8.

Developing "Pedagogical Content Knowledge" To Improve Teaching

"The Understanding Science approach focuses on the intersection of teachers' knowledge about science and their understanding of how students learn," says WestEd's Mayumi Shinohara, who directs the project with Kirsten Daehler. "Research tells us that teachers who have strong content knowledge and sciencespecific pedagogical skills are more effective than other teachers — they ask students higher-level questions, for example, and are better at helping their students apply science concepts."

To address this dual focus on content and pedagogical content knowledge, each Understanding Science session engages participants in a carefully designed sequence of activities. First, educators conduct their own hands-on investigation of a science concept, such as electrical circuits. Later, they discuss a "teaching case," an expert educator's journal-like description of teaching this same science concept to a class of students. The written cases include student work samples, descriptions of materials and activities, dialogue, and teacher thinking.

A case focused on an electrical circuit lesson, for example, includes a fourth-grade teacher reflecting on what students were getting out of the lesson:

> "While the Bulb-Battery-Wire Activity definitely helped students learn how to light the bulb, it misled many to think that light is pretty much the same thing as electricity.... I think it's important for students to have a more nuanced understanding of light and electrical current.... I still think the activity is a great way of teaching those ideas, but I wonder what additional scaffolding is needed...."

Professional development workshop facilitators guide participants to carefully analyze how students in the case understand and misunderstand the science idea, as revealed in their explanations and questions and in how they represent concepts such as "complete circuit" or "current" in drawings. Facilitators also encourage participants to critically analyze the instructional decisions that the case teacher makes when students become confused or need reinforcement on important concepts.

For example, participants might evaluate the effectiveness of a teacher's series of questions about student drawings and comments about circuits:

> "Is there always a circle connection between the two ends of the battery" I asked (students).... "Remember what you learned about bulbs yesterday. When you look at these circuits that light up, what patterns do you see?"

Through discussing the various instructional perspectives and solutions that arise in their own science investigations and in the cases, participants in Understanding Science sessions develop ideas for improving instruction.

Between professional development sessions, participants complete "Classroom Connection" assignments, in which they use the approaches they're learning in the sessions to explore science ideas, language, and thinking with their own students. Debriefing this homework with other participants offers educators a deeper look at how various strategies apply across classrooms and grade levels.

Supporting Literacy Skills for Science Learning

Understanding Science participants come to recognize the importance of students' ability to understand the academic content and their capacity to represent what they know through speaking and writing. An important goal of the Understanding Science initiative is to narrow the science achievement gap between English learners or students with low literacy skills and their grade-level peers. To help narrow this gap, the professional development sessions model a learning environment of collaborative inquiry, one filled with talk and writing about science concepts that are grounded in participants' hands-on investigations.

When classroom conversation and writing are promoted as ways to understand science concepts, academic language and vocabulary can be continually taught and reinforced in meaningful ways. For example, one of the teaching cases includes the following analysis of how students' drawings and writing about electrical current reflected their understanding of this difficult concept:

> Students' work pointed out some things I hadn't noticed before. Even though I was careful to talk about "electrical current," they all used the word electricity." I also don't know where they're getting the idea that current is "used up" or "shared." Are they actually talking about "energy?" We don't really get into energy at this grade level, but it would be correct to say the bulbs transform the electrical energy into heat and light. In that way, it is okay to say that energy gets "used up."

Strong Results for Teachers and Students

The Focus on how students think about science concepts and on the teaching needed to improve their science literacy has proven effective. With support from the National Science Foundation, the Institute of Education Sciences, the Stuart Foundation, and the Stone Foundation, the Understanding Science project has worked with more than 1,000 teachers over the past decade. An extensive multi-year study of the project demonstrated that:

- Teachers learned science, developed more sophisticated understanding of pedagogical content knowledge, and maintained these gains over time.
- Teachers reported changes in theirgeneral classroom practices, not just for the course topics they studied.
- Students of all entering abilities showed significant gains in science — and low-performing students improved the most.2

Building on these strong results, project developers plan to publish in the coming years a full set of 15 professional development courses on the major concepts of K–8 earth, life, and physical sciences. Shinohara reports that she and her colleagues have chosen topics sufficiently focused so that educators can get "traction" in the content and approach in 24 hours, but big enough to be relevant and meaningful to their teaching.

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1 W. S. Carlsen, "Teacher Knowledge and Discourse Control: Quantitative Evidence from Novice Biology Teachers' Classrooms," Journal of Research in Science Teaching 30 (1993): 471–481; W. S. Carlsen, "Subject-matter Knowledge and Science Teaching: A Pragmatic Perspective," in Advances in Research on Teaching, Vol. 2 (Greenwich, CT: JAI, 1991), 115–186; C. A. Druva & R. D. Anderson, "Science Teacher Characteristics by Teacher Behavior and by Student Outcome: A Meta-analysis of Research," Journal of Research in Science Teaching 20, no. 5 (1983): 467–479; M. Hashweh, "Effects of Subject Matter Knowledge in the Teaching of Biology and Physics," Research and Teacher Education 3 (1987): 109–120.

2 J. I. Heller, Final Evaluation Report for Science Cases for Teacher Learning: Impact on Teachers, Classrooms, and Students, Project Years 2000-2003 (submitted to WestEd and Stuart Foundation, 2006).