

## ***Research Findings***

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Evidence from research supports the success of Understanding Science professional development courses. Multiple years of extensive research indicate that the Understanding Science professional development program builds teacher knowledge, strengthens classroom practice, and positively impacts student achievement. The studies showed significant gains of more than one standard deviation in participating teachers' science knowledge and gains in their students' understanding, including significantly higher levels of student achievement in classrooms of project teachers than those of comparable non-participating teachers in the same schools. An especially encouraging result is that low-performing students made the biggest gains. (Heller, Daehler, & Shinohara, 2003; Heller & Kaskowitz, 2004; Heller, 2006).

### **Background**

Following is a summary of the methods and findings from this multi-year evaluation (2000-2003) of several existing Understanding Science courses for K-8 teachers. This evaluation, led by Dr. Joan I. Heller, focused on the project's impact on participating teachers, including changes in their science content knowledge and pedagogical content knowledge, and corresponding changes in reported teaching practices and therefore in their students' opportunities to learn science. In addition, the evaluation examined whether student understanding of electricity and magnetism concepts was impacted by their teachers' participation in the project. The study was designed to allow comparisons between *different cohorts* of teachers who participated in the project in two successive years; *over time* between pre and post measures as well as at a one-year follow-up; and for *different amounts and kinds of experience* in the project, including teachers who participated as discussants, facilitators of case discussions, and case writers.

Each school year, a different cohort of teachers participated in between six and eight Understanding Science course sessions for between 20-50 hours of professional development. Data were collected from teachers in 2000-01 (Cohort 1,  $n = 48$ ) and 2001-02 (Cohort 2,  $n = 36$ ), and from students in 2000-01 ( $n = 166$  in project classrooms,  $n = 105$  in comparison classrooms). The classrooms were located in four San Francisco Bay Area districts, in urban settings with a highly diverse student population with respect to ethnic background and primary language.

An important part of the project's work has been developing an evaluation framework (see Table 1 on the following page). This framework makes explicit the core, critical features of the staff development model, as well as theoretical connections between those features and target outcomes. The four major features of the Understanding Science experience are listed in the leftmost column:

- Exploration of Scientific Meanings
- Focus on Student Thinking
- Critical Analysis of Practice
- Experience in a Learning Community

Each of these features in turn are intended to have associated teacher-, classroom-, and student-level outcomes, which we describe in the second, third, and fourth columns. For example, the exploration of scientific meanings is intended to strengthen teachers' understanding of those

concepts, which would influence student opportunities to learn through the way that those concepts are taught, thereby affecting students’ understanding of those concepts.

This evaluation provides evidence that teachers who participated in the existing Understanding Science courses made significant gains in relation to all of these target outcomes. Participating teachers demonstrated improvements in their science content knowledge along with positive changes in their pedagogical content knowledge and teaching practices that supported improved student learning. (Heller and Kaskowitz, 2004).

*Table 1: Evaluation Framework of the Understanding Science Project*

Critical Features of the Understanding Science approach	Teacher Outcomes	Classroom Outcomes	Student Outcomes
<b>Exploration of Scientific Meanings.</b> Teachers discuss, investigate, and think carefully about the meaning of specific science concepts in each case.	Rich and accurate understanding of the science concepts in the cases; confidence and positive attitude toward learning, doing, and teaching science.	Discussion and activities focus on the meaning of science concepts. Science content meets grade-level expectations in accuracy and coverage.	Accurate understanding of science concepts in the cases; grade-level appropriate knowledge of science content; ability to observe, look for patterns, and draw conclusions.
<b>Focus on Student Thinking.</b> Teachers examine and interpret student work, talk, and behaviors in each case to determine what students understand and are thinking.	Heightened attention to student thinking; understanding of what is important for students to know about the content; knowledge about what makes science learning difficult for students.	Instruction and assessment elicit and build on student thinking and deal directly with what is difficult for students; curriculum addresses what is important for students to know about the content.	Ability to avoid or move beyond misconceptions and errors; skill in thinking and communicating scientifically.
<b>Critical Analysis of Practice.</b> Teachers analyze the effectiveness and coherence of instructional practices, activities, materials, and scientific representations in each case.	Pedagogical reasoning is analytical, complex, and detailed; ongoing reflection about the effectiveness of instructional practices, activities, and materials; skill in making science comprehensible to students.	Instructional practices and materials communicate and develop the meaning of science concepts; coherent, structured sequences of inquiry activities; instructional decisions are adjusted as a result of ongoing analysis of student understanding.	In-depth understanding of science concepts; ability to represent scientific meanings in a variety of ways.
<b>Experience in a Learning Community.</b> Teachers participate in a learning community where members engage in a process of collaborative inquiry about scientific ideas and phenomena and reflection on the teaching and learning of science.	Ability to engage in and support collaborative inquiry; deliberately plan instruction that supports collaborative inquiry; believe that explanations and discussions are essential parts of learning science.	Students engage in collaborative inquiry to make sense of scientific ideas; students interact with each other to learn science; opportunity for students to articulate and justify their scientific ideas and explanations.	Skill in collaboratively making sense of science; ability to articulate and justify scientific ideas and explanations.

## **Method**

Our approach was to build an evaluation mosaic by conducting studies to investigate selected outcomes in the evaluation framework, beginning with teacher and student outcomes (columns 2 and 4) that might be related to the project's focus on Exploration of Scientific Meanings (row 1), Focus on Student Thinking (row 2), and Critical Analysis of Practice (row 3). (For additional details on the mosaic approach to evaluating professional development, see Heller, Daehler, & Shinohara, 2003.)

During 2000-01 and 2001-02, these target outcomes were investigated with a combination of data collection methods including written surveys, content tests, interviews, and focus group discussions that yielded both qualitative and quantitative data and provided insight on the impact of the Understanding Science project from a variety of sources. Heller Research Associates conducted several small-scale but intensive studies, relying in part on repeated measures given to different cohort groups of teachers and their students, before and after the Understanding Science course. Some of the studies also included comparisons between project and "control" groups. Surveys, content tests, and in-depth interviews focusing on teachers' pedagogical content knowledge were administered to a subset of teachers at the beginning of the year and in the spring. In addition, focus groups were conducted in the spring to gather information from teachers in all groups.

The in-depth interview was designed to measure the project's impact on teachers' science content knowledge and pedagogical content knowledge in relation to electric circuits. The interview contained questions about teachers' (a) conceptualizations of student difficulties understanding circuits; (b) instructional approaches to addressing those difficulties; (c) instructional approaches to helping students understand a specific area of science content—in this case, what would happen if one of the bulbs were unscrewed in a parallel circuit; (d) interpretations of strengths and weaknesses in student responses to that problem; and (e) instructional strategies they would use to help those particular students develop a stronger understanding of what happens in the circuit in terms of the flow of electricity. The combination of questions elicited detailed information about teachers' content knowledge, instructional strategies, reasoning about student knowledge, and pedagogical content knowledge.

In addition, during the 2000-01 school year, student achievement was measured through content assessments in electricity and magnetism that were administered in a subset of participating teachers' classes to students two weeks before and two weeks after the FOSS electricity and magnetism unit was taught. Content test data were also collected from students in comparable classrooms of non-participating teachers during that year. To ascertain whether items were measuring what they were intended for, cognitive interviews were conducted with fourth grade students of varied backgrounds. Students participated in one-on-one "think aloud" sessions in which they were asked to explain their thinking as they completed the content assessments.

## **Results**

Overall the results provide strong evidence that teachers participating in Understanding Science professional development are learning both content and pedagogical content knowledge, their teaching is improving, and student achievement is rising as a result of project activities. One especially encouraging result was that the greatest increase in science achievement was seen among low-performing students, thus helping to close the achievement gap. (Ellinger, 2004; Heller & Kaskowitz, 2004; Heller, Daehler, Shinohara, & Kaskowitz, 2004).

**Teachers value the rigor.** In each study over a five-year period, and at elementary and middle-school levels, participating teachers consistently rate the Understanding Science courses “among the best” professional development experiences in their careers. A typical response includes praise for the unique opportunity “to discuss the science concepts *and* the effectiveness of the instructional practices used *and* the common misunderstandings of both children and teachers. In most science professional development, it’s mostly one or the other.” Overall, teachers report how rare this environment is in which they are “being challenged to think” during professional development. “You walk away agitated, . . . [you’re] still trying to figure it out. [I] drive home and I’m still thinking about it. . . . That doesn’t happen in a workshop.”

**Teachers acquired better understanding of key science concepts.** In every study of *Understanding Science* courses, differences between mean pre- and post-course scores on teacher science tests were statistically significant. These outcomes were observed repeatedly for elementary teachers in early trials of the course when it was taught by project staff, and later in a national field test in which the course was disseminated for delivery by staff developers in each geographical area. As shown in Table 1, elementary and middle school teachers in *Understanding Science* courses showed statistically significant gains on tests of science content knowledge, with effect size statistics ranging from just under one standard deviation unit difference between post-test and pre-test means ( $ES = .69$ ) to more than one standard deviation difference ( $ES = 1.25$ ). To provide some order of magnitude of effect sizes, Cohen (1988) defines effect sizes as “large,  $d = .8$ ,” “medium,  $d = .5$ ,” and “small,  $d = .2$ .” (p. 25).

In-depth interviews also revealed extensive changes in the depth, breadth, and accuracy of teachers’ content knowledge, in ways that were directly related to the content goals of the courses. In the second year of a study, results showed even greater changes in teachers’ content knowledge, a fact that is especially powerful in light of the transfer of course delivery, from project staff to teacher-facilitators.

**Table 1. Pre- and Post-Course Percent Correct on Content Tests for Participating Teachers**

Group	Test scores		Significance		ES
	Pre-test	Post-test	<i>t</i>	<i>p</i>	
2001-02 Oakland elementary teachers ( <i>n</i> = 17)	50.1% (15.5)	62.7% (17.1)	3.80**	.003	0.92
2001-02 BASEE elementary teachers ( <i>n</i> = 11)	60.3% (14.4)	76.0% (17.5)	4.15**	.001	1.25
All 2001-2002 elementary teachers ( <i>n</i> = 28)	54.1% (15.6)	68.0% (18.2)	5.70***	.000	1.08
2006 SF Bay Area middle-school teachers ( <i>n</i> = 9)	68.4% (23.3)	78.7% (19.1)	2.08*	.035	0.69

\* $p < .05$ , \*\* $p < .005$ , \*\*\* $p \leq .001$

**Teachers demonstrated increased complexity, accuracy, and detail in their pedagogical content knowledge (PCK).** Participation in an Understanding Science course resulted in more sophisticated pedagogical content knowledge as demonstrated through in-depth individual interviews requiring reasoning about student work and instruction. In post interviews, teachers were better able to give examples of the kinds of difficulties students might have, describe potential difficulties in more detail, and more often gave examples of how these difficulties were

manifested in student work or performance. More often teachers made explicit links between specific student challenges and instructional interventions. The teaching strategies they described reflected deeper and more accurate insight into the nature of science content. A follow-up study showed the gains in teachers' content and pedagogical content knowledge were maintained a full year later.

**Teachers reported changes in their teaching of electricity and magnetism and in their science teaching in general.** In focus groups, during interviews, and on written surveys, teachers described profound changes in their attitudes, beliefs, and instruction that extended to other parts of their teaching. For example, more than 90% of the teachers reported on a survey that Understanding Science courses influenced not only their teaching of electricity and magnetism, but their science teaching in general. As one 4<sup>th</sup> grade teacher from Oakland, California put it:

“Before this [Understanding Science] class, I tended to teach science lecture style or read chapters and discuss them. . . . When I used FOSS before the classes, I was asking more information-based questions, and the hands-on work was like an extended demo. With WestEd I began to ask questions that every kid can bring something to, like ‘What happens if...?’ . . . ‘Can you get it to work a different way?’ ‘Why do you think so?’ Those types of questions brought the science alive. I also learned how to . . . figure out what understanding [my students] are truly demonstrating or not.”

There were also significant increases in teachers' pre- and post-survey ratings of how confident they were in their understanding of all major topics in electricity and magnetism ( $p < .005$ ), and participants showed a new enthusiasm for teaching electricity and magnetism and for learning with their students. At first we wondered if teachers might avoid courses that focused on such challenging science, but we found as teachers enjoyed success with this tough content, they in turn felt that *all* science was manageable. By participating in collegial learning groups, they in essence learned how to learn science and reported learning cross-cutting strategies for teaching.

**Students had a greater opportunity to learn grade-level science.** Surveys showed that participating teachers taught more grade-level appropriate electricity and magnetism curriculum units to their students than they had previously and than their colleagues did in comparable classrooms. As one teacher said, “I love teaching science but I was hesitant before to teach magnets and electricity since I had no knowledge of how things work.” The teachers also became clearer as to what students should know about electricity and magnetism and more discriminating regarding what students were actually learning.

**Students of project teachers demonstrated greater understanding of electricity and magnetism than students of their teachers' colleagues who did not participate.**

With respect to student achievement, a comparison group study showed that scores on a test of electricity and magnetism of 166 students of teachers in the project increased significantly from pre- to posttest whereas there were no significant pre post gains among students of non-participating teachers who had also taught a unit on electricity and magnetism during the same period. An analysis of covariance showed that posttest scores for the project group were significantly greater than for the comparison group after any initial differences in the entering achievement levels of the students were controlled statistically, indicating that students in the project group ended the year with more knowledge about electricity and magnetism.

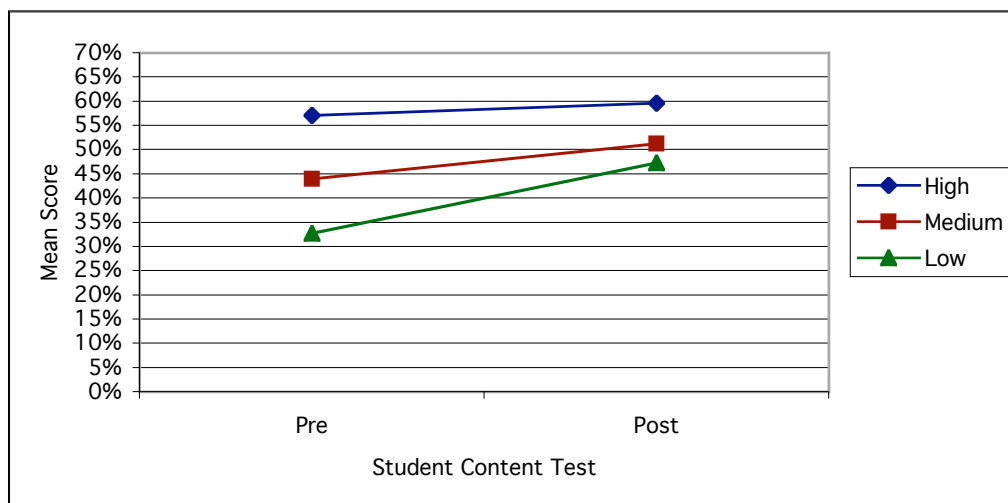
Having ascertained that students of participating teachers exhibited stronger achievement than comparison students, and the project was at least as effective for EL students as for proficient

English speakers, we then asked whether the project was equally efficacious for students of different entering ability levels. On the basis of pre-test performance, project students were divided into top, middle, and bottom thirds (referred to hereafter as “High,” “Medium,” and “Low” groups). The results showed that pre-post mean gains were statistically significant for students at all levels of entering ability (see Table 2). The greatest increase was seen among low-performing students of project teachers, who improved, on average, by one standard deviation unit. This result is important because it has the effect of closing a portion of the achievement gap that previously existed among these groups of students (as depicted in Figure 1).

**Table 2. Comparisons of Pre and Post Percentage Correct Scores on Content Tests for Students with High, Medium, and Low Pre-test Scores**

Ability Group based on Pre-test Scores	Pre-test	Post-test	<i>t</i>	<i>p</i>	<i>ES</i>
High – Pre-test score > 49.1% ( <i>n</i> = 58)	57.12% (6.63)	59.63% (8.74)	2.38*	.021	0.31
Medium – Pre-test score between 38.6% and 49.1% ( <i>n</i> = 49)	43.95% (2.65)	51.25% (11.02)	4.88**	.000	0.70
Low – Pre-test score < 38.6% ( <i>n</i> = 59)	32.71% (6.71)	47.26% (12.11)	7.80**	.000	1.02

\*  $p < .03$ , \*\*  $p < .001$



**Figure 1.** Graph of pre and post percentage correct scores on electricity and magnetism test for students with pre-test scores classified as high (*n* = 58), medium (*n* = 49), and low (*n* = 59).

## References

- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Heller, J. I. (2006). *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.
- Heller, J. I., Daehler, K., & Shinohara, M. (2004, April). *Using a pedagogical content framework to determine the content of case-based teacher professional development in science*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Vancouver.
- Heller, J. I., Daehler, K., & Shinohara, M. (2003, Fall). Connecting all the pieces: Using an evaluation mosaic to answer an impossible question. *Journal of Staff Development*, 24, 36-41.
- Heller, J. I., & Kaskowitz, S. R. (2004). *Final evaluation report for Science Cases for Teacher Learning: Impact on teachers, classrooms, and students, Project years 2000 – 2003*. Technical report submitted to Stuart Foundation.