difficult to teach and difficult for the students to learn. Finally, it all depends on whether the teachers are able to see a relationship between their teaching enactment and their students’ learning outcomes, and be able to act on these findings that contribute to teachers’ learning, resulting in better teaching and learning.

**TRACKING TEACHERS’ LEARNING IN PROFESSIONAL DEVELOPMENT CENTERED ON CLASSROOM ARTIFACTS**

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*This paper reports on the methodological approach and research findings from the Turning to the Evidence project, a project that measured teacher learning across two professional development programs focused on using classroom artifacts to study algebraic thinking. The Turning to the Evidence project investigates these programs as the context for inquiry into two overarching research questions: (1) what do teachers learn by participating in professional development that uses classroom records and artifacts? And, (2) what aspects of their learning do they apply to their own classroom practice?*

How do mathematics teachers continue to develop the knowledge, skills, and habits of mind that enable them to teach well and to improve their practice over time? This is a fundamental question for researchers and has generated a considerable amount of work in the areas of “teacher learning,” much of which is scattered across diverse areas of literature including changes in beliefs, knowledge, decision-making, pedagogical approaches, and even teachers’ sense of self-efficacy and identity. Part of the task of getting a handle on what is meant by teacher learning is to be explicit about the aspect of learning that is under investigation, and the reasons for finding it important as a focus of study.

One promising context for promoting and studying teachers’ learning is in mathematics professional development (PD) that makes use of classroom artefacts (Ball & Cohen, 1999). Several research projects have suggested that that practice-based PD projects that utilize artefacts of practice, such as classroom video and student work, are effective tools in efforts to increase teachers’ opportunity to learn mathematics knowledge for teaching (Smith, 2001). By bringing the everyday work of teaching into the PD setting, these tools enable teachers to unpack the mathematics in classroom activities, examine instructional strategies and student learning, and discuss ideas for improvement (Driscoll et al., 2001; Schifter et al., 1999a, 1999b; Seago et al, 2004).

This paper reports on the *Turning to the Evidence* (TTE) study, which examines the impact on teachers’ learning of two PD programs focused on algebraic thinking: *Fostering Algebraic Thinking Toolkit* (Driscoll et al., 2000) and *Learning and Teaching Linear Functions: VideoCases for Mathematics Professional Development*.
(Seago, Mumme, & Branca, 2004). The TTE study grew out of the observation that, while there is currently considerable interest in using classroom records and artefacts as a tool for mathematics teachers’ PD, as a field we know surprisingly little about what teachers actually learn by working with artifacts or how they integrate their learning into daily classroom practice (Wilson & Berne, 1999). This research effort has two foci: the PD seminars (examining what teachers learn by working with artifacts and records) and the classroom (examining ways that teachers bring learning from their PD seminars into their classroom practice).

THE STUDY CONTEXT

Data have been gathered in four research sites in the U.S.: two groups of teachers on the east coast who participated in Fostering Algebraic Thinking (AT) PD and two west coast districts participating in VideoCases for Mathematics Professional Development (VCM) PD. All of the groups were facilitated by the lead authors of the respective programs, (Driscoll for the AT groups and Seago for the VCM groups), ensuring high fidelity of implementation. Both seminars involved 12, three-hour sessions. Both PD programs involved 36 hours of PD (12, three-hour sessions). The VCM groups completed all 12 sessions in a single academic year (2003-2004) and the AT groups completed the PD over the course of three semesters (October 2003-January 2004). In all, 49 middle and high school teachers participated in the groups, 20 in the AT groups and 33 in the VCM groups. Sixteen teachers (four from each site) are being followed more closely to create case studies. Seminar participants included both veteran and early career teachers. Slightly more than a quarter of the teachers participating in the PD had been in the classroom for 5 years or fewer; the entire group of seminar participants averaged approximately 10 years of teaching. In addition to the 49 PD participants, 25 teachers served as a comparison group for our pre/post written measures. These comparison teachers came from the same districts as the PD participants.

DATA SOURCES

We have collected both quantitative and qualitative data. The quantitative data includes two paper-and-pencil instruments administered to participants at the beginning and end of the PD described below.

Mathematics survey was designed to assess teachers’ algebra knowledge—both their own ability to solve algebra problems and their ability to recognize algebraic thinking that is characteristic of students—that is, aspects of “mathematics knowledge for teaching” (Ball & Bass, 2000; Ball, Hill, & Bass, 2005). In constructing the survey, we drew heavily on items from the University of Michigan “Learning Math for Teaching” database (Hill et al., 2004) and also included items used to assess teachers’ learning in California Mathematics Professional Development Institutes (California Professional Development Institute, 2002; Hill & Ball, 2003). Staff added a few additional items. The instrument contains both multiple choice items and open response items. Both
administrations of the instrument included confidence scales for each problem answered; in addition, at the end of the post-program administration, we gave teachers their pre-program booklets and asked them to write a few sentences about any differences they noticed between the two.

Artifact Analysis was designed to assess what teachers attended to when analysing classroom artifacts. It consists of a mathematical task, a five-minute video clip of a classroom discussion and student solution methods around the mathematical task, a series of four questions about the video, three different written student work to comment upon, a question about the accuracy of each piece of student work and a final question about what lesson would come next.

The qualitative data collected includes video of all of the PD sessions as well as video of the classroom lessons observed by TTE staff. (In addition to the classroom video itself, we audio taped interviews with the teachers before and after each classroom visit).

OVERALL FINDINGS

Because our research goals did not relate specifically to understanding the learning of early career teachers, our data analyses have centered on changes in the participant group as a whole. (However, we expect that the issues our work raises hold equally well for teachers at any point in their careers.) Overall, results indicate that teachers learned to take a more analytic stance to their work with classroom artifacts, attending to the mathematical implications of the thinking embodied in the artifacts and noticing the potential in students’ thinking, rather than stopping at an assessment of students’ weaknesses.

For example, the post-program artifact analysis indicates that PD participants were more likely than the comparison teachers to comment on specific mathematical ideas in their analysis of both the video clip and the accompanying written work samples. In addition, their work was more grounded in evidence, and they were more attentive to student potential (vs. being evaluative) than the comparison group teachers. Additionally, analyses of the seminar sessions themselves indicated that over the course of the PD, participants’ discussions of classroom artifacts not only showed the same kinds of shifts as we observed on the written measures, but that the teachers internalized many of the strategies for attending to artifacts that we had articulated as goals for the project (Nikula, Goldsmith, Blasi, & Seago, 2006).

Analysis of teachers’ learning with regard to the development of mathematical knowledge for teaching (MKT) is somewhat more complex. Our analysis of changing discourse over the course of the PD indicates that teachers’ discussion of artifacts became deeper and more mathematically coherent, as well more focused on unpacking students’ understanding relative to the artifact’s underlying mathematical concepts. However, our quantitative data are difficult to interpret. While we do not have comparable data for comparison teachers, and therefore cannot unequivocally ascribe the changes in the mathematical discussions to the PD experience, we are
confident that the increasing sophistication of teachers’ mathematical analysis was, in fact, a result of their PD experiences and that comparison teachers would not have demonstrated such changes. However, our data from the mathematics survey fails to distinguish between PD and comparison groups in terms of overall score (both made modest improvements from pre- to post-test). A more qualitative analysis of the instrument has suggested that teachers may make subtle shifts in important aspects of their mathematical knowledge for teaching; for example, a number of the seminar participants tended to use the mathematical language (and ideas) of the seminar in their responses to the post instrument, demonstrated more fluent and flexible use of mathematical representations, and identified solutions that involved specific strategies and mathematical content related to the PD experience.

Preliminary analysis of classroom lessons suggests that teachers’ transfer of the increased attention to the mathematical ideas behind student thinking observed in the PD to their classroom practice is modest. We did notice that some teachers were making small, subtle changes in their classroom instruction, such as emphasizing the connections between diagrammatic representations of a problem and symbolic representations, or seeking to make students’ thinking more public. In general, it seems that the process of reconstructing classroom practice is a slow moving one, subject to relatively undramatic changes as teachers work to integrate their work in PD into their ongoing, daily instruction.

**REFLECTIONS ON OUR MEASURES**

In conducting our research, we have found a tension between looking for measures that could help us characterize aspects of teachers’ learning and honouring the fact that the work of developing one’s practice involves deepening both subject area and pedagogical knowledge (and integrating them) and is a difficult, intense, and often emotionally challenging undertaking. Teachers must do this work at the same time they are responsible for the education of their students—a situation that has been likened to redesigning and building an airplane while it is in flight. At times, we have felt that the data from our written measures capture only part of the story.

This has been particularly true for the mathematics survey. The Learning Math for Teaching database of items (Hill et al., 2004) allows researchers to assess the mathematical knowledge for teaching of large numbers of teachers and to compare results across studies. However, our findings of improvement in both seminar participants and comparison teachers have left us with questions about how to interpret the data. In addition, it has raised questions for us about the alignment of the survey’s “grain size” relative to the kinds of learning we have found through more careful analysis of changing mathematical discourse in the seminars themselves (Seago & Goldsmith, 2006).

This leaves us with a challenge which, we think, is one that is shared by the field as a whole: how to measure dimensions of teacher learning in ways that allow comparisons across studies, seem to capture the essence of the learning, and also