

THE IMPACT OF LEARNING AND TEACHING LINEAR FUNCTIONS PROFESSIONAL DEVELOPMENT

Nanette Seago, Catherine Carroll, Tom Hanson, Steve Schneider
WestEd, USA

This study examines the impact of Learning and Teaching Linear Functions (LTLF) professional development materials on teachers' mathematics understanding and teaching practices, as well as students' resulting algebra proficiency, learning, and achievement. Learning and Teaching Linear Functions are modular, video-based professional development materials designed to enable teachers to deepen their specialized content knowledge by understanding ways to conceptualize and represent linear functions within their teaching practice. The intervention consisted of a one-week summer institute and on-line support throughout the academic year.

INTRODUCTION

New directions in mathematics education demand new approaches to professional development. Teacher educators need to help teachers develop richer instructional practices that integrate emphasis on developing students' conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition through mathematical investigation, problem solving, and discourse (Kilpatrick et al., 2001). There is a groundswell of interest in creating and using mathematics professional development materials that focus on helping teachers examine the interplay between mathematical content, teacher, students and context (Smith, 2001). Rooted in the everyday work of teaching, classroom artefacts such as student work, videos or narrative accounts, become invaluable tools for learning teaching in practice-based materials (Lampert and Ball, 1998; Driscoll et al., 2001; Seago et al., 2004). Videos in particular have been found to be a promising tool in supporting teacher learning in professional development (Seidel et al. 2005).

The best practices for supporting such professional development involve providing experiences that are intensive in focus and extensive in duration (Garet et al., 2001) and that are “practice-based”—that is, that offer teachers the opportunity to examine the mathematical skills and understanding that undergird the classroom curriculum, investigate students' mathematical thinking, and explore instructional practices that support student learning (Cohen and Hill, 2001; Thompson and Zeuli, 1999). By focusing on developing the understanding, skills, and dispositions that teachers use in daily practice, this “practice-based” professional development provides a meaningful context for teachers' learning.

The Linear Functions for Teaching study focuses its work on the practice-based video case materials, *Learning and Teaching Linear Functions* (LTLF) (Seago, Mumme and Branca, 2004), which are designed to enable teachers to deepen their understanding of

ways to conceptualize and represent algebra content within their teaching practice. LTLF is premised on the idea that using artefacts of practice within a well-structured PD program can promote mathematical knowledge for teaching (Ball & Cohen, 1999). This idea is supported by a variety of learner-centred, inquiry-based theoretical traditions, including constructivist and situative perspectives on learning (Cobb, 1994). These perspectives share the notion that engaging in challenging, problem-based, collaborative, and socially shared activities is likely to promote an expanded knowledge base (Borko, et al., 2005). The *Learning and Teaching Linear Functions* materials were designed with all of these features in mind and include an analytic framework, explicit tasks, teacher learning goals, and facilitation supports.

THEORETICAL FRAMEWORK

The theoretical frame for the LTLF video case materials is adapted from the work of Deborah Ball and colleagues (Ball and Cohen, 1999; Cohen, Raudenbush & Ball, 2003) that incorporates research on both teaching and learning. The content of the video case materials focuses on the interactions between the teacher, the content (in this case, linear functions tasks), and the students, within the context of an authentic classroom environment (see Figure 1, page 3). The materials are designed to be used by a teacher educator who is faced with a similar set of relationships: the interactions between the teacher educator, the content (in this case, teaching and learning of linear functions), and the teachers he/she works with. To assist the teacher educator in using the PD materials productively with teachers, in-depth resource materials are provided to facilitate teachers' knowledge development. Resource materials include: mathematics content information, probing discussion questions, and other facilitation guidance specific to the materials.

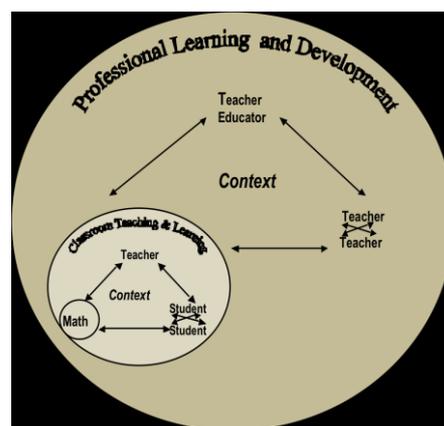


Figure 1: Theoretical Framework (Adapted from Cohen, Raudenbush, & Ball, 2003).

As Ball and her colleagues have noted, teachers' mathematical knowledge for teaching is of central importance with respect to interactions around the content with students (MKT; Ball, Hill & Bass, 2005; Ball, Lubienski & Mewborn, 2001). Their research has shown that MKT relates to the quality of teachers' classroom work and positively predicts gains in their students' mathematical achievement (Hill, 2010; Hill, Rowan & Ball, 2005). MKT can be understood as the knowledge that teachers need to effectively

carry out the work of teaching. MKT incorporates subject matter knowledge as well as pedagogical content knowledge (Ball, Thames, & Phelps, 2008).

RESEARCH STUDY

The following research questions guide the study:

- *Do teachers participating in the LTLF professional development program exhibit greater increases in knowledge and skills regarding linear functions*
- *Do teachers participating show greater integration of LTLF-based teaching strategies into their instructional practice than teachers in control classrooms?*
- *Do students in LTLF classrooms demonstrate greater increases in algebra understanding (in particular linear functions) and engagement in mathematics learning than their counterparts in control classrooms?*

The research questions focus on the impacts on teachers and students. For teachers, research on teacher knowledge and instructional practice over two academic years. For students, research focused on students in LTLF classrooms in the year that teachers received the professional development and students in LTLF classrooms in the year subsequent to teacher LTLF professional development.

Study design and timeline

Learning and Teaching Linear Functions was designed to enable teachers deepen their understanding of mathematics content, students' mathematical thinking, and instructional strategies. The study took place from spring 2011 to spring 2013 in 62 schools serving middle grades in California. Schools and teachers were recruited in winter and spring 2011. Participation in the study was voluntary. The intervention involved a one-week summer training course using the LTLF first module, *Conceptualizing and Representing Linear Relationships*, a sequential series of eight 3-hour sessions designed to enrich teachers' ability to teach linear relationships and deepen their own detailed knowledge of the distinctions and linkages among the various representations. Each session has at its core one or two digital video clips of a mathematics classroom. Additionally, participants received academic year online follow-up support in year 1 and year 2 (~20 PD hours).

The efficacy of LTLF was investigated using a pre-test/post-test cluster randomized trial design with one intervention group and one control group. Teachers were randomly assigned to an intervention or control group, in which they remained until the conclusion of the study. The trial was conducted in 43 districts throughout California. A qualitative video study of a smaller sample of six randomly selected teachers is used to examine traceable elements of implementation of the LTLF PD, validate and explain quantitative findings, and to identify factors that influence the success of the pedagogical approach.

A total of 81 teachers in 62 schools were randomly assigned to groups – 41 to intervention and 40 to control. About 77 percent (63) of the original 81 teachers completed the study and provided teacher and/or student test score data. The 63 teachers who were retained in the analytic sample after attrition came from 51 schools in 36 districts. Student quiz data were obtained from 1,645 students (934 intervention and 711 control). There was no evidence to suggest that the experimental groups differed with respect to attrition or missing data patterns.

With an average of 28 students served by each participating teacher, the sample size is sufficient for detecting program impacts on student outcomes of 0.22 standard deviations for primary academic outcomes and 0.31 for item-level data. The estimated minimum detectable effect size for the teacher knowledge assessment (see below) was 0.36 standard deviations.

Key outcomes and measures

Table 1 below lists the study’s key outcome variables—teachers’ knowledge for mathematical instruction, teacher practice and conceptualization of student work, and student knowledge.

Outcome	Measure
<p>Teacher Knowledge</p> <p>Teachers’ knowledge for teaching</p>	<p>Learning Mathematics for Teaching Assessment</p>
<p>Teacher Practice</p> <p>Teachers’ conceptualization of teaching, students and student work</p> <p>Elements of PD that get used by teachers in their classroom</p>	<p>Artefact Analysis</p> <p>Videotaped lessons</p>
<p>Student Knowledge</p> <p>Knowledge of Algebra I</p> <p>Knowledge of Linear Functions</p>	<p>California Standardized Test – Algebra I</p> <p>4 Released NAEP items</p>

Table 1: Outcome measures.

Each outcome measure is described in more detail below.

Learning Mathematics for Teaching Instrument. All participating intervention and control teachers completed the pre-test, post-test, and follow-up assessment of the online version of the Teacher Knowledge Assessment System (TKAS) (Hill, Blunk, Charalambous, Lewis, Phelps, Sleep, & Ball, 2008). Teachers were randomly assigned to complete alternative forms of the assessment. These measures have been used with over 2000 teachers, yielding information about reliability and item characteristics. The reliabilities for these scales range from 0.71 to 0.84.

Artefact Analysis Assessment. All teachers completed an artefact analysis assessment prior to and within one month after the summer institute. The artefact analysis assessment asks teachers to solve a mathematics task and to provide written responses about (a) a 5-minute video clip of 6th grade students presenting solutions to a linear function problem and (b) three specific samples of student work (each representing a different typical student error). Written responses were coded based on the extent to which teacher interpretations focus on students' potential understandings, are backed by evidence, and focus on specific mathematics content.

Videotaped Lessons. Video observations of 56 lessons from a randomly selected subset of teachers, using portable video camcorders and audio equipment, have been completed. Teachers received a package including a flip camera, microphones, tripod, and instructions. Each teacher videotaped two lessons in 2011–2012 and two more lessons in 2012–2013 (one each in fall and spring of each academic year). Coding of the lessons using Studiocode software is currently underway. The purpose of the coding is to identify “traceable elements” from the PD—those elements that were key to the intervention and that we expect to see in classrooms where teachers are implementing what they learned in the institute. Once criteria and coding schemes are finalized, we will score video data to gain scorer reliability of at least 0.8, after which we will code each video for evidence of the key elements and score as high, medium or low fidelity of implementation.

Algebra 1 CST. Students' knowledge of algebra I is assessed using California's end-of-course Algebra I CST. The criterion-referenced CST has been administered annually to all students through 2013. Baseline (pre-test) assessments of mathematics proficiency are used as covariates in the impact analysis models. For this study, data are collected on performance of participating teachers' students in Spring 2011 (prior to the intervention) and again in Spring 2012 and 2013. At this time, these data are still being collected and are not reported on in this paper.

NAEP Items. Students' knowledge of linear functions is assessed with four publicly released NAEP problem-solving items. To date, two of the items have been scored by blinded raters as incorrect, minimal, partial, satisfactory, and extended. Inter-rater agreement on the two items ranged from 0.77 to 0.92.

ANALYSIS AND RESULTS

To estimate program impacts, outcomes for teachers and students in intervention group classrooms were compared with those for teachers and students in control group classrooms. Multilevel regression models were used to analyze the effects of the LTLF program and to account for data clustering by teacher and school (Goldstein 1987; Raudenbush and Bryk 2002; Murray 1998). The impact analyses controlled for baseline (pre-test) measures of outcome variables and other teacher, student-, and school-level covariates.

Estimated impacts

Teacher Knowledge. The results for the Learning Mathematics for Teaching (LMT) assessment suggest that intervention teachers scored about 25 percent of a standard deviation higher than control teachers on the LMT test after the first academic year. This difference, however, is not statistically significant at conventional levels, and the intervention/control group difference was no longer apparent after the second academic year.

Teacher Practice. The results of the artefact analysis suggest the LTLF is associated with changes in teachers' perceptions of student potential and analysis of student work. Although no pre-intervention differences were apparent between intervention and control teachers, at post-test, intervention teachers were substantially more likely to (1) indicate an understanding of students' potential than control teachers on the student work task and (2) focus on the mathematical content of student work than their counterparts in the control group. There was also a greater tendency for intervention teachers to use evidence to justify their inferences with regard to student work and analysis of the classroom video, although these differences were statistically significant at conventional levels.

Student Knowledge. Estimated LTLF impacts on the Algebra I CST are not yet available as collection of state assessment scores is ongoing. Although analyses of the four NAEP items assessing performance on linear functions problems suggest that LTLF is not associated with significant increases in knowledge, there was a tendency for students in intervention classrooms to score higher on the two open-ended items ($p=0.10$ and 0.18).

SYNOPSIS

The impact analyses indicated that LTLF resulted in modest short-term improvements in teachers' knowledge for teaching mathematics, recognition of students' mathematical understanding on student work, and attention to the appropriate mathematics content on student work. However, intervention/control group differences in knowledge for teaching mathematics were completely diminished at the 2nd post-test, as scores of teachers in the control group "caught-up" to their counterparts in the intervention group. We therefore conclude that the year 1 impacts of LTLF on teacher knowledge do not persist in year 2. The impacts (short and long term) on instructional practice are still under investigation.

For student outcomes, only the results the NAEP linear function items are available for analysis at the present time. Although the results favor the intervention group for two of the four items, LTLF is not associated with increases in performance on this measure in a statistically significant manner.

The Learning and Teaching Linear Functions professional development research is one study situated in the larger context of other research on PD interventions. The field is relatively new and has a thin empirical research base (Hill, Beisiegel, & Robin, 2013).

A particular challenge is determining what features of the PD cause an impact on teacher practice and student knowledge. Indeed, there is much to be learned about the development and delivery of effective PD, as well as the research of PD outcomes. The LTLF PD study in the process of developing evidence of impact of a PD intervention and is learning important contributions to the field regarding effective methods and measurement of impact studies.

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