Professional Development Effects on Teacher Efficacy: Results of Randomized Field Trial

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ABSTRACT **We designed a professional development (PD) program to increase the teacher efficacy of mathematics teachers. We randomly assigned 106 Grade 6 teachers in 1 school district to treatment and control conditions in a delayed-treatment design. The PD explicitly addressed 4 sources of teacher-efficacy information identified in social-cognition theory (Bandura, 1997). Treatment teachers outperformed control-group teachers on 3 measures of teacher efficacy, but results were statistically significant only for efficacy for classroom management. We attributed the teacher-efficacy effects of the PD (6% of the variance) to the priority given in the PD to management of classroom discussions and overt attempts by PD leaders to redefine teacher conceptions of classroom success.**

Keywords: mathematics education, professional development, teacher efficacy

Research on the antecedents and consequences of teacher efficacy is a growth industry, and for good reason. Teacher efficacy, at the individual and collective level, consistently predicts a host of enabling teacher beliefs, functional teacher behaviors, and valued student outcomes. Despite the importance of the construct, few researchers have reported the effects of interventions intended to increase teacher efficacy. We consider the potential of professional development (PD) as a stimulus for enhancing teacher beliefs about their ability to bring about student learning. We illustrate our argument with data from a randomized field trial in which we examined teacher-efficacy outcomes of a PD program for Grade 6 mathematics teachers.

Theoretical Framework

The Construct

Teacher efficacy is a teacher's expectation that he or she will be able to bring about student learning. It is a specific case of *self-efficacy*; that is, "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 2) directed toward the teacher as an agent of student achievement. Teacher efficacy influences behavior through (a) cognitive processes (especially goal setting), (b) motivational processes (especially attributions for success and failure), (c) affective processes (especially control of negative feelings), and (d) selection processes (Bandura, 1993; 1997). Teachers who believe that they will be successful set higher goals for themselves and their students, try harder to achieve those goals, and persist through obstacles more than do teachers who are not sure of their success. Individuals who believe that they will fail avoid expending effort because failure after trying hard threatens self-esteem. Self-efficacy is situational; it is not a generalized expectancy. It develops from a subject's appraisal of past experience with a task or with similar activities, although perceptions of efficacy can be modified by other sources of information, such as observing the performances of others (Bandura, 1997).

Teacher efficacy is a self-perception, not an objective measure of teaching effectiveness. However, researchers (Goddard, Hoy, & Woolfolk Hoy, 2004; Ross, 1998; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) demonstrated that teachers with high efficacy beliefs generate stronger student achievement than do teachers with lower teacher efficacy. The effects of teacher efficacy on student achievement can be attributed to several factors, as we show in the following paragraphs.

First, those scoring higher on teacher-efficacy measures are more likely to try new teaching ideas, particularly techniques that are difficult, involve risks, and require that control is shared with students (Ross, 1998). The use of such strategies contributes to enhanced achievement.

Second, high-efficacy teachers use classroom management approaches that stimulate student autonomy. Student achievement is higher because those management strategies keep students on task more effectively than custodial management techniques (Woolfolk, Rosoff, & Hoy, 1990).

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Third, high-efficacy teachers are more successful than are low-efficacy teachers because they attend more closely to the needs of lower ability students. Ashton, Webb, and Doda (1983) found that low-efficacy teachers concentrate their efforts on the upper ability group, giving less attention to lower ability students who the teachers view as potential sources of disruption. In contrast, we determined that high-efficacy teachers have positive attitudes toward low-achieving students, build friendly relationships with them, and set higher academic standards for this group than do low-efficacy teachers.

Fourth, teacher efficacy leads to changes in teacher behavior that modify students' perceptions of their academic abilities. As student efficacy becomes stronger, students become more enthusiastic about schoolwork and more willing to initiate contacts with the teacher—processes that directly affect achievement (Ashton et al., 1983; Ashton & Webb, 1986). Supporting that view is evidence that teacher efficacy has a delayed impact on student achievement. For example, Midgley, Feldlaufer, and Eccles (1989) found that teacher efficacy correlated with achievement in the spring, but not in the fall.

Finally, teacher efficacy influences student achievement through teacher persistence. Teachers with highly perceived efficacy view student failure as an incentive for greater teacher effort rather than conclude that the causes of failure are beyond teacher control and cannot be reduced by teacher action.

In social cognition theory (Bandura, 1997), teacher efficacy develops through reflection on sources of efficacy information. The most important sources are *mastery experiences*, that is, episodes in which teachers demonstrate to themselves that they are competent instructors. As an example, teachers observe the progress of a difficult-to-teach student. Mastery experiences are enhanced through feedback from superiors and social validation that connects the achievement outcomes to teacher actions. Other sources of efficacy information include (a) vicarious experience (social comparison by observations of successes and failures of others), (b) persuasion by peers and superiors (a weak source but important to teachers with little experience in a domain), and (c) physiological and affective states. Teacher efficacy forms early in preservice experience and the early years of teaching and remains relatively stable thereafter (Woolfolk Hoy & Spero, 2005).

Theory of Teacher Change

Figure 1 shows the theory of teacher change that we developed in a qualitative study of a Grade 8 teacher experiencing PD, which focused on teacher self-assessments, with explicit attention to sources of efficacy information (Ross & Bruce, 2007). At the core of Figure 1 is teacher self-assessment in which teachers (a) observe their effect on student achievement, (b) make a judgment about how well they attained their instructional goals, and (c) reflect

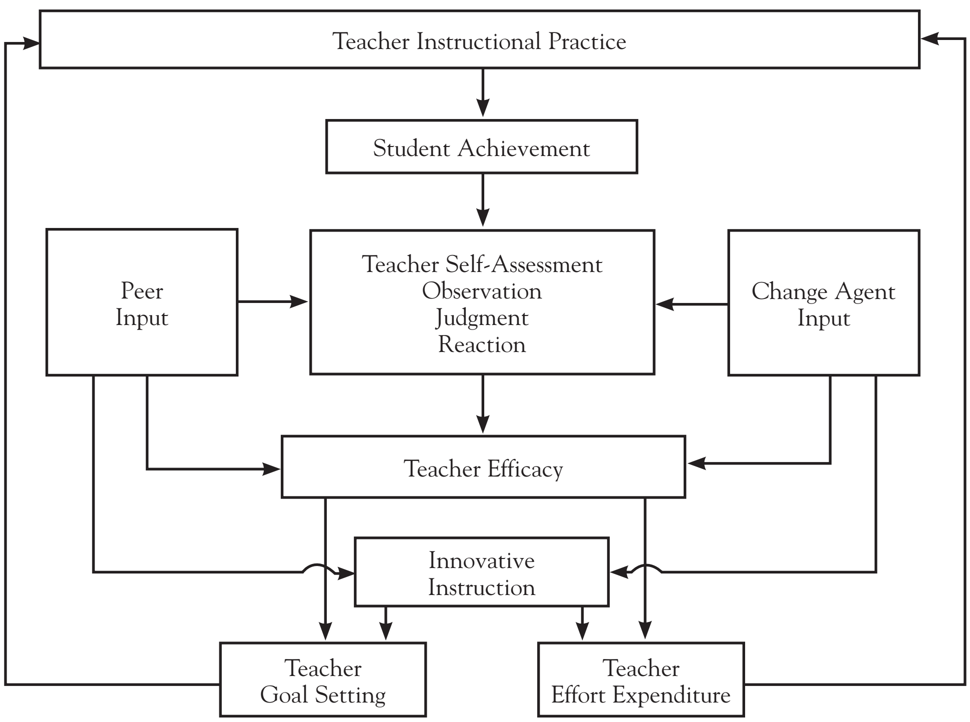

FIGURE 1. Model of teacher self-assessment as a mechanism for teacher change (J. A. Ross & C. Bruce, 2007).

on their satisfaction. Those individual processes can be influenced by other agents, particularly peers and change agents (in this article, PD presenters). The model suggests that peers and PD presenters provide teacher efficacy information that influences self-assessments made by PD participants. The contributions to teacher self-assessments, in concert with information on innovative instruction, heighten teacher efficacy, which influences teacher goal setting and effort expenditure. In the model, changes in goals and effort contribute to improved instructional practice, which results in higher student achievement.

Naturalistic Change in Teacher Efficacy

Uncontrolled manipulations have demonstrated that teacher beliefs in their professional capacities are malleable. For example, a government-imposed detracking plan had an initially negative effect on the teacher efficacy of exemplary mathematics teachers (Ross, McKeiver, & Hogaboam-Gray, 1997). The teachers believed that they were capable of teaching different ability groups in separate classes but found that their skills could not be integrated readily to teach a mixed-ability group. Teacher expectations of success declined because they could not predict whether the new methods would produce student learning in untracked classes; the teachers lacked a reservoir of mastery experiences in comparable settings. The researchers found that the negative effects of restructuring dissipated over time. Teacher confidence returned as teachers developed new ways of working with heterogeneous classes and discovered that achievement, particularly of lower ability performers, was as high, if not higher, than it had been in tracked classes. Teacher efficacy increased as a consequence of personal coping strategies (especially certainty about professional goals and control of emotional states) and social processes (particularly collaboration with same-subject peers).

From the perspective of social-cognition theory, increased teacher efficacy occurred when the teachers accumulated experiences in which they (a) perceived themselves as professionally masterful, (b) observed teachers like themselves being successful, (c) persuaded each other that they could teach the new curriculum, and (d) engaged in stress-reduction practices. The four sources of efficacy information are the mediators that explain why detracking, and the coping strategies of those able teachers, influenced teacher beliefs about their effectiveness.

Effects of PD Training

A small number of researchers have investigated the effects of PD on teacher efficacy. Given the stability of teacher efficacy (see reviews by Ross, 1998; Woolfolk Hoy & Spero, 2005), some researchers who reported increased teacher-efficacy scores over the duration of a PD program argued that improved scores are sufficient evidence of a program effect (Bolinger, 1988; Robardey, Allard, & Brown, 1994). The assumption is questionable, particularly if the gains dissipate after the program ends (Ohmart, 1992). The argument is more persuasive for those studies in which researchers demonstrated that teacher-efficacy gains are higher among those who faithfully implement the practices recommended by the PD (Rimm-Kaufman & Sawyer, 2004; Ross, 1994; Stein & Wang, 1988).

Studies of teacher-efficacy effects of PD with control groups are rare. Fritz, Miller-Heyl, Kreutzer, and MacPhee (1995) examined the effects of PD focused on developing teachers' personal self-esteem, internal locus of control, and communication skills. Treatment teachers obtained higher teacher-efficacy scores on the post- and delayed posttests than did control-group teachers. Effects were strongest for teachers identified as frequent users of curriculum materials distributed in the program. Fritz et al. argued that although they compared volunteers to a convenience sample of control teachers, their claims of a program effect were valid because the two groups had equivalent teacher-efficacy scores on the pretest. Edwards, Green, Lyons, Rogers, and Swords (1998) found that a peer-coaching program had a small positive effect on teacher efficacy. Although Edwards et al. found that teacher-efficacy scores of treatment and control-group teachers were equivalent on the pretest, the groups differed on prior inservice credits, and sample attrition was significantly higher in the treatment than in the control group.

Despite the methodological flaws in individual studies, prior research suggests that PD might contribute to higher teacher efficacy. First, virtually all those studies made an overt attempt to strengthen teachers' instructional skills. More effective teaching should increase the likelihood of teachers obtaining mastery experiences, the strongest predictor of self-efficacy. Researchers who distinguished PD effects by fidelity of implementation found that teacher-efficacy effects were higher for teachers who more diligently applied PD ideas in their classrooms (Fritz et al. 1995; Rimm-Kaufman & Sawyer, 2004; Ross, 1994; Stein & Wang, 1988). Second, some of the programs provided for participant interaction (Edwards et al., 1998; Robardey et al., 1994; Ross, 1994), thereby increasing opportunities for vicarious experiences (i.e., observing successes of other teachers) and creating settings in which teachers could be persuaded that they would be successful with new teaching strategies.

Research Questions

In our examination of the PD program, we focused on standards-based mathematics teaching. Implementation of mathematics education reform threatens the teacher-efficacy beliefs of teachers in several ways. For example, the reform asks that teachers (a) implement unfamiliar instructional strategies, (b) draw on disciplinary knowledge they may not have, (c) engage lower ability students in abstract reasoning, and (d) launch classroom discussions that may take unpredictable directions (Ross, McDougall, & Hogaboam-Gray, 2002; Smith, 1996). Given that high teacher efficacy is likely to facilitate implementation of standards-based mathematics teaching, we designed a PD program in which one of the goals was to strengthen teacher efficacy. The guiding research question for the study was, "Will Grade 6 teacher PD that explicitly addressed teachers' sources of efficacy information increase teacher efficacy beliefs?" The specific research questions were:

1. Will the PD increase teacher-efficacy beliefs about teachers' ability to engage students?
2. Will the PD increase teacher-efficacy beliefs about teachers' ability to implement appropriate teaching strategies?
3. Will the PD increase teacher-efficacy beliefs about teachers' ability to manage students?

Method

Sample

Our study is a randomized field trial involving all elementary schools in a single Canadian district. Canadian schools are experiencing many of the accountability pressures common to schools in industrialized democracies. For example, as in the United States, standardized assessments are conducted in several grades (including Grade 6) by an external testing organization to measure student achievement of core curriculum objectives. In Ontario, the province in which we conducted our study, external assessments have low stakes for students. The stakes are much higher for teachers and administrators; the schools publish annual reports and explicitly monitor improvement plans for underachieving schools. However, the coercive policies for school improvement (such as reconstitution) and differentiated targets to reduce differences among student groups that are embedded in legislation, such as the No Child Left Behind Act (2001), have not been introduced in Canada.

Over 95% of the students in the district were Canadian born; 52% were girls, 48% were boys, 15% were special-needs students, 1% spoke a language other than English at home, and average family income in the district was near the mean for the province of Ontario. The sample consisted of 106 Grade 6 teachers representing 85% of the Grade 6 teacher population for the district. All Grade 6 teachers in each school were assigned randomly to the treatment or control group. Treatment teachers received the PD during September–December 2003. Control teachers received the same PD at the end of the study (January–April 2003). We used teacher-attendance records to confirm that on the whole, teachers participated in the PD sessions to which they were assigned. We found that a few teachers drifted from the late to the early PD. The reasons for violating random assignment were idiosyncratic rather than systemic. For example, a few teachers thought that they were in the fall PD group because the sessions were held at their school.

Sources of Data

Teacher efficacy, the dependent variable, consisted of 12 items from the Teachers' Sense of Efficacy scale (Woolfolk Hoy, n.d.), adapted for mathematics teaching. The scale included (a) 4 items for *efficacy for engagement* (e.g., "How much can you do to motivate students who show low interest in mathematics?"), (b) 4 items for *efficacy for teaching strategies* (e.g., "How well can you implement alternative mathematics strategies in your classroom?"), and (c) 4 items for *efficacy for student management* (e.g., "How much can you do to calm a student who is disruptive or noisy during mathematics?"). Response options were on a 5-point Likert-type scale anchored by 1 (*nothing*) and 5 (*a great deal*). Table 1 shows the complete item set. We used the Teachers' Sense of Efficacy scale because it is becoming a standard instrument in the field and has had high reliability in previous administrations. Evidence shows concurrent validity with the Rand items and Gibson and Dembo (1984) scales (Tschannen-Moran & Woolfolk Hoy, 2001, 2002), and it is faithful to the prevailing conception of teacher efficacy (Tschannen-Moran et al., 1998). We administered the teacher efficacy measure to both groups 2 weeks prior to the start of the PD and 2 weeks after the final PD session.

At the time of the pretest, we also administered other measures to test the equivalency of the groups. Each of these measures was plausibly linked to teacher efficacy. *Standards-based mathematics teaching* was measured with 20 items (e.g., "I regularly have my students work through real-life math problems that are of interest to them"). Response options were on a 6-point Likert scale anchored by 1 (*strongly disagree*) and 6 (*strongly agree*). Ross, Hogaboam-Gray, and McDougall (2003) found that the Teachers' Sense of Efficacy scale had high reliability (α = .81 in two samples involving 2,600 teachers) and validity. The validity evidence consisted of correlations of survey scores with a mandated performance assessment in Grade 6 mathematics, congruence with classroom observations of a small sample of teachers, and demonstrations that teachers who were similar in their claims about using a standards-based text series differed in their use of the text in ways predicted by the survey. We also included other teacher background measures: *previous training in mathematics*, consisting of 4 items (e.g., "Did you major in mathematics at university"), and *professional development in teaching mathematics*, consisting of 3 items (e.g., "Have you taken additional qualification courses that focused on mathematics education?").

Treatment

The PD consisted of 1 full day, followed by three 2-hr after-school sessions. We held sessions in three sites to reduce group size. Communicating mathematics ideas was the organizing theme because it affects multiple aspects of mathematics teaching. In each of the sessions, presenters (who were mostly classroom teachers) modeled specific dimensions of standards-based mathematics teaching. Teachers constructed mathematics knowledge by using rich Grade 6 curriculum tasks. After each session, teachers applied the teaching principles in their own classrooms, collected artifacts that reflected student thinking, and shared their experiences with colleagues at the next session. (For a detailed description of the PD, see Ross & Bruce, 2006).

The PD contributed to the four sources of efficacy information identified by Bandura (1997) in multiple ways:

Mastery experiences. Teacher efficacy involves an appraisal of the difficulties of the teaching task, weighed against an assessment of personal competence (Tschannen-Moran et al., 1998). Our first strategy for increasing teacher opportunities for mastery experiences was to strengthen competence by incorporating features of effective mathematics PD identified in Hill's (2004) review: (a) active teacher learning, (b) examples from classroom practice, (c) collaborative activities modeling effective pedagogy, (d) opportunities for reflection, (e) practice and feedback, and (f) focus on content. By increasing competence, we anticipated that teachers would be more successful in the classroom, according to teachers' usual criteria (e.g., student responsiveness to teacher prompts), which would enhance teacher efficacy.

Our second strategy for increasing mastery experiences was to redefine success. For example, instead of defining a lesson as successful, if most students obtained the correct answer by using conventional algorithms, we urged teachers to focus on (a) the depth of conceptual understanding that students reached, (b) the extent to which students contributed to the construction of their knowledge, and (c) their ability to communicate mathematics ideas. To influence teacher criteria, we provided teachers with a rubric containing 10 dimensions of mathematics teaching. For each dimension, four levels of teacher practice ranged from transmission teaching to standards-based teaching (Ross et al., 2003). We selected three dimensions for special attention. Experienced teachers modeled standards-based teaching by using Grade 6 tasks. While modeling, presenters encouraged teachers to judge their success in terms of familiar standards (e.g., student use of mathematics language) and standards less familiar (e.g., students' invention of problem-solving procedures and sharing, explaining, and justifying their solutions). When debriefing between-session practice, we focused on the new standards for judging success. We tried to reduce teacher perceptions of the difficulty of the instructional task and increase beliefs in their ability to teach in new ways.

Vicarious experiences. Teacher efficacy increases when teachers observe their peers bringing about student learning. As our first strategy, we enlisted experienced teachers from the same district to demonstrate new practices because models are more credible when they share characteristics with the learners. As our second strategy, we structured the debriefing sessions (through a series of prompts given to pairs and groups of four) to highlight classroom success so that teachers would perceive their peers as being successful. As a third strategy, we presented evidence (from Ross et al., 2002) to demonstrate that standards-based teaching could be implemented by generalist teachers and that doing so leads to higher student achievement.

Social persuasion. Although persuasion is a weak source of efficacy information (Bandura, 1997), it is important when teachers have little prior experience in a domain. For teachers who had not experienced standards-based mathematics teaching as a student, nor attended workshops on mathematics education reform, presenters offered frequent assurances that implementers would be successful.

Physiological and affective states. Feelings of stress, anxiety, and nervousness communicate negative information about competence for a task. We addressed that dimension indirectly by sequencing the introduction of teaching ideas from least threatening (use of manipulatives) to more threatening (sharing control of the lesson with students). We also attempted to minimize fears about problems that could occur.

While the treatment group was participating in the PD, control teachers continued with their regular programs. Following administration of the posttest surveys, the control group received the same PD.[1]

Results

Descriptive Analysis

We examined the distributional properties of all variables. We defined outliers as 3.0 standard deviations above or below the mean; we reduced the few deviations that we found to the mean +/– 3.0 standard deviations. We defined variables as normally distributed if the skewness index was below 3.0 and kurtosis was below 10.0 (Kline, 1998). All variables met the criteria.

Table 1 shows the results of an exploratory factor analysis (principal axis with promax rotation and Kaiser normalization) on the teacher-efficacy items. Three factors explained 69% of the variance. All items loaded on only one factor (shown in bold in Table 1); the weakest item loading was .47. The highest cross loading was .37; most cross loadings were near 0. We found that one item ("How much can you assist families in helping their children do well in mathematics?") fit the instructional strategies dimension better than it did the student-engagement dimension. The remaining items all loaded on the scales identified by Tschannen-Moran and Woolfolk Hoy (2001).

Table 2 shows *descriptives* for the teacher variables (number of cases, means, standard deviations, and reliabilities), along with separate sample *t* tests of the groups on pretest variables. Table 2 shows that when the study began, there were no significant differences between the treatment and control groups on any of the teacher efficacy variables. Also, there were no statistically significant differences on the self-reported teaching practices survey. The bottom half of Table 2 shows no differences between the two groups

TABLE 1. Results of Principal Axis Factor Analysis of Teacher-Efficacy Items

	Factor		
Item	Instructional Strategies Efficacy	Engagement Efficacy	Class Management Efficacy
How much can you do to motivate students who show low interest in mathematics?	.171	**.673**	.001
How much can you do to get students to believe they can do well in mathematics?	.029	**.892**	–.075
How much can you do to help your students value learning mathematics?	–.092	**.927**	.063
How much can you assist families in helping their children do well in mathematics?	**.468**	.108	.056
To what extent can you craft good questions about mathematics for your students?	**.901**	.003	–.126
How much can you use a variety of mathematics assessment strategies?	**.649**	–.002	.064
To what extent can you provide an alternative explanation or example when students are confused about mathematics?	**.659**	–.017	.092
How well can you implement alternative mathematics strategies in your classroom?	**.776**	.035	–.003
How much can you do to control disruptive behavior during mathematics?	–.058	–.034	**.850**
How much can you do to get children to follow classroom rules about mathematics?	.051	.221	**.552**
How much can you do to calm a student who is disruptive or noisy during mathematics?	.024	–.019	**.911**
How well can you establish a classroom management system for mathematics with each group of students?	.369	–.102	**.481**

Note. Principal loadings are shown in boldface type.

on previous mathematics education training. Table 1 also indicates that all teacher instruments were of adequate reliability (i.e., Cronbach's α = .81–.86).

Did Teacher PD Increase Teacher-Efficacy Beliefs?

Teacher efficacy was relatively stable over the duration of the study; pre- and postcorrelations were r = .61–.76. We conducted a multivariate analysis of covariance using GLM, the General Linear Modeling program in SPSS. The dependent variables were the posttest scores on the three teacher-efficacy variables. The covariates were the pretest scores on the same variables. The independent variable was experimental condition. The top panel of Table 3 shows the multivariate results: all three pretest teacher-efficacy variables had a significant effect. However, experimental

TABLE 2. Description of Study Variables and Tests of Group Equivalence

Variable/group	M	*SD*	α	*t(df)*	*p*
Premath teaching					
Treatment	4.72	0.44			
Control	4.67	0.52	0.81	0.51(104)	0.618
Prestudent engagement efficacy					
Treatment	4.13	0.62			
Control	4.14	0.78	0.86	–0.81(104)	0.936
Preinstructional strategies efficacy					
Treatment	4.01	0.56			
Control	3.88	0.58	0.82	1.13(104)	0.263
Preclassroom management efficacy					
Treatment	4.60	0.40			
Control	4.42	0.56	0.81	1.86(84.41)	0.073
Poststudent engagement efficacy					
Treatment	4.25	0.61			
Control	4.13	0.65	0.85		
Postinstructional strategies efficacy					
Treatment	4.02	0.55			
Control	3.86	0.58	0.84		
Postclassroom management efficacy					
Treatment	4.60	0.37			
Control	4.33	0.54	0.84		
One or More Math Summer Institutes					
Treatment	14%				
Control	10%				
One or more mathematics conferences					
Treatment	56%				
Control	50%				
AQ mathematics course					
Treatment	3%				
Control	2%				
One or more university mathematics courses					
Treatment	48%				
Control	65%				
M.Ed. degree					
Treatment	11%				
Control	8%				

Note. n = 57 for treatment group; n = 49 for control group.

condition was not statistically significant, even though it explained 5.8% of the variance.

Because the total sample in this study was relatively small, we examined the univariate effects. The bottom panel of Table 3 shows the results. The corrected model explained 49% of the engagement variance, 60% of the instructional-strategies variance, and 42% of the student-management variance. A large covariate effect existed for each of the dependent variables. In every case, the pretest score for the matching posttest variable accounted for the largest portion of the variance. There was a significant univariate effect for the treatment on one of the teacher-efficacy variables (classroom management), accounting for 5.7% of the total variance. Table 4 shows that teachers in the treatment group scored higher than did teachers in the control group on all of the teacher-efficacy variables after posttest means were adjusted by pretest scores, even though only the classroom management efficacy differences were statistically significant.

We examined whether the effect of the inservice on teacher efficacy for classroom management was moderated

TABLE 3. Effects of Professional Development on Teacher Efficacy

Independent variable	Dependent variable	*F*	*df*	*p*	n^2
	Multivariate results				
Intercept	—	8.67	3, 99	.001	0.208
Preengagement efficacy	—	11.77	3, 99	.001	0.263
Preinst strategies efficacy	—	26.78	3, 99	.001	0.448
Preclass management efficacy	—	10.01	3, 99	.001	0.233
Group	—	2.02	3, 99	.116	0.058
	Univariate results				
Corrected model	Postengagement efficacy	24.46	4,101	.001	0.492
	Postinstructional strategies efficacy	38.18	4,101	.001	0.602
	Postclass management efficacy	18.9	4,101	.001	0.428
Intercept	Postengagement efficacy	3.29	1,101	.072	0.032
	Postinstructional strategies efficacy	4.61	1,101	.034	0.044
	Postclass management efficacy	26.27	1,101	.001	0.206
Preengagement efficacy	Postengagement efficacy	32.69	1,101	.001	0.245
	Postinstructional strategies efficacy	5.716	1,101	.019	0.054
	Postclass management efficacy	3.186	1,101	.077	0.031
Preinstructional strategies efficacy	Postengagement efficacy	0.365	1,101	.547	0.004
	Postinstructional strategies efficacy	66.93	1,101	.001	0.399
	Postclass management efficacy	0.182	1,101	.670	0.002
Preclass management efficacy	Postengagement efficacy	5.306	1,101	.023	0.050
	Postinstructional strategies efficacy	0.008	1,101	.930	0.001
	Postclass management efficacy	24.22	1,101	.001	0.193
Group	Postengagement efficacy	0.792	1,101	.376	0.008
	Postinstructional strategies efficacy	1.119	1,101	.293	0.011
	Postclass management efficacy	6.135	1,101	.015	0.057

TABLE 4. Postteacher Efficacy Scores Adjusted by Pretests

	Adjusted posttest means		
Factor	Treatment group	Control group	Mean differences
Engagement Efficacy	4.23	4.15	.08
Instructional Strategies Efficacy	3.98	3.90	.08
Class Management Efficacy	4.56	3.78	.58

by prior knowledge of mathematics education (represented by attending one or more mathematics education conferences) or by prior knowledge of the discipline (represented by taking one or more university mathematics courses). We ran a univariate analysis of covariance in which the dependent variable was the posttest teacher efficacy for classroom management score, the covariate was the pretest score on the same indicator, and there were three independent variables: (a) attendance at a minimum of one mathematics conference, (b) experimental condition, and (c) interaction of condition and covariate. We repeated the analysis by replacing attending a mathematics conference with taking one or more university mathematics courses. Treatment-group membership continued to be a significant predictor of posttest efficacy for classroom management in both the analyses. Treatment teachers had greater confidence in their ability to manage mathematics classrooms than did control teachers, regardless of whether teachers had received extra training in mathematics education or whether they had additional disciplinary knowledge.

Discussion

We investigated the effects of PD on the self-efficacy beliefs of Grade 6 mathematics teachers. We were motivated by the threats to teacher confidence posed by the introduction of standards-based mathematics teaching and anticipated that PD explicitly addressing four sources of efficacy information would have a positive impact. We found an effect, although the results were statistically significant only for teachers' confidence in managing students.

Standards-based mathematics teaching poses substantial management challenges. In traditional mathematics classes, the role of teachers is to keep students attentive and on task; the role of students is to listen, watch, and imitate. In reform mathematics education, however, the teachers' job is to guide student explorations; students' task is to expand their conceptual grasp and integrate formal knowledge with practical knowledge. The latter process threatens classroom management: First, the teacher has to share control of the classroom agenda, eliciting and following student constructions. Second, reform teaching requires more than new scripts; it means that the direction of the lesson should be molded during the lesson, requiring reflection in action (Schön, 1987). Third, the explorations of mathematics ideas may lead to areas in which the teacher's understanding is shaky, challenging the teacher's status as the prime knowledge expert. That incidence can be very threatening because knowledge expertise is one of the four power bases from which teachers work (Levin, Nolan, Kerr, & Elliott, 2004). Fourth, teachers have to teach students how to take greater responsibility for their own learning, a role that students may resist.

We found that the PD program had a positive effect on teacher expectations about their ability to handle student-management issues in the mathematics classroom. The differences were small (about 6% of the variance). The result was robust across teacher background variables, suggesting that the PD benefit was shared by all teacher groups, including those who were least prepared in disciplinary and pedagogical content knowledge. Although there were slight increases in the other dimensions of teacher efficacy measured by the Teachers' Sense of Efficacy Scale, only the changes in classroom management were statistically significant. We suspect that teachers' confidence in their ability to engage student interest and to use new instructional strategies follows confidence in classroom management. There is a long line of research (e.g., Fuller, 1969; Waller, 1932) demonstrating the primacy of classroom management in teacher concerns.

The PD in this model provided additional support for the model in Figure 1. We attribute the effects of our intervention to the elements of the PD designed to influence sources of teacher-efficacy information. Two strategies designed to increase teacher opportunities for mastery experience were especially important: First, we strengthened teachers' ability to manage classroom discussions by (a) providing rich tasks, (b) modeling the use of these tasks in simulations, (c) requiring that teachers apply principles presented in the PD in their own classrooms, and (d) debriefing classroom experiences with evidence brought by teachers of their student responses to the tasks. Second, we explicitly redefined teacher conceptions of success, emphasizing that student knowledge construction is the prime criterion for appraising teacher success. In addition, we provided opportunities for teachers to benefit vicariously by structuring PD activities in which participants recounted to their peers success in implementing reform practices in their own classrooms. Our results provide additional support for the model in Figure 1 in the form of quantitative data derived from a relatively large Grade 6 teacher sample to complement qualitative evidence generated from a case study of a Grade 8 teacher (Ross & Bruce, 2007).

Our findings are important because teacher efficacy is a powerful predictor of teacher outcomes, such as willingness to implement new instructional ideas (Allinder, 1994; Riggs & Enochs, 1990; Ross, 1994; Supovitz & Turner, 2000), as well as being a predictor of student achievement (Goddard et al., 2004; Ross, 1992; Ross & Cousins, 1993; Ross, Hogaboam-Gray, & Hannay, 2001). Teacher beliefs about their capacity tend to be highly stable (pre- and postcorrelations for the control across teacher efficacy dimensions were r = .70) so that even small changes were noteworthy.

A key strength of this study is the use of a randomized field trial involving virtually all teachers in a school district—our search of the literature found no other instances of this design to measure the effects of mathematics PD. Although a few teachers drifted from the condition to which they were assigned and some teachers were dropped from the study because they did not complete the data-collection requirements, the deviations from randomness were not systematic, and there were no pretest differences between conditions. The key limitations were that we did not measure teachers' instructional practice (a key component of Figure 1), the duration of the PD was short, and we did not examine the lasting impact of the changes in teacher efficacy (because by the end of the school year the control group had received the same PD). We believe that the inclusion of a measure of teachers' instructional practice would have produced positive correlations between degree of change in teacher efficacy and extent of instructional innovation. We also believe that a longer duration would have shown greater PD impact. We suspect that contextual variables would determine how well the effects of the PD endured.

Directions for Research

We recommend that researchers continue exploring the effects of PD on teacher beliefs about their capacity to teach mathematics in a standards-based framework. First, we recommend that researchers include credible measures of instructional practice and student achievement in randomized field trials of PD programs. Such designs are exceedingly rare, in part, because of the substantial funding required. Although we support the criticisms of Feuer, Towne, and Shavelson (2002) of the narrow definition of "scientifically based research" in the No Child Left Behind Act (2001) and the What Works Clearinghouse (n.d.), such a definition makes randomized field trials more feasible.

To date, the basis for the claim that mathematics PD influences teacher efficacy, which in turn contributes to improved instruction and student achievement, has been demonstrated by a focus on individual links in the program theory, not by simultaneous measurement of the central elements of the model.

Second, we recommend intensive qualitative studies of the effects of PD on teacher beliefs about their capacity, focusing especially on the extent to which PD influences teacher choices about the sources of efficacy information they attend to and how they process efficacy information. Usher and Pajares (2005) reported evidence (from children) that the sources of efficacy information vary among subgroups and that a fifth source of self-efficacy, *invitations*, is for some groups a more important source of information than are mastery experiences. Invitations are the messages that we send to ourselves (and others) that indicate how able and valuable we feel that we (and others) are. We anticipate that invitations and disinvitations (i.e., negative messages about ability) may be a useful construct for exploring how PD influences teacher beliefs about their ability, particularly in settings in which peer coaching is a central mechanism for supporting growth in teacher professionalism. Our interest is theoretical and practical: We believe that clarifying the linkages among teacher efficacy, sources of efficacy information, and their influence by peers and PD designers is central to the development of more powerful treatments than are currently available.

Implications for Practitioners

Finally, the practical implications of our study suggest directions for PD. Presently, PD for mathematics teachers focuses on the acquisition of instructional skills, a necessary but not sufficient condition for improved teaching. Our research indicates that explicit attention to teacher cognitions, particularly teacher beliefs about their capacity to bring about student learning in the standards-based mathematics curriculum, is an essential complement to skill acquisition. The model in Figure 1 shows that teacher efficacy is a key energizer of teacher goal setting and persistence. Our results indicate that PD that addresses sources of efficacy can contribute to creating more confident teachers.

NOTES

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1. We ran missing values analysis on the data, which employs regression methods to estimate missing values and uses the residuals to add a random component to the regression estimates of the missing scores. We conducted an exploratory factor analysis (principal axis, promax rotation with Kaiser normalization) on the teacher-efficacy items because previous research indicated that the factor structure was not stable (Woolfolk Hoy, n.d.). We aggregated all items into scales by calculating the mean score for each teacher on each variable. After examining the distributional properties of study variables, we tested the equivalence of the two experimental conditions with separate sample *t* tests for each variable. Conducting multiple *t* tests inflates Type I error and increases the likelihood of finding statistically significant differences. The usual defense against exaggerated Type I error is to apply a Bonferroni adjustment. However, because we were predicting no differences between the treatment and control groups, the more rigorous procedure was to use unadjusted alphas. We addressed the research question in a multivariate analysis of covariance using GLM: (a) posttest scores were three dimensions of teacher efficacy, (b) pretest scores were covariates, and (c) the independent variable was the experimental condition.

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