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Effects of Professional Development on Teacher Efficacy:

Results of a 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 one school district to treatment and control conditions in a delayed treatment design. The PD explicitly addressed four sources of teacher efficacy information identified in social cognition theory (Bandura, 1997). Treatment teachers outperformed control group teachers on three 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.

Effects of Professional Development on Teacher Efficacy:

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Research on the antecedents and consequences of teacher efficacy is a growth industry, and for good reason: Teacher efficacy, at both 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 there have been few studies reporting the effects of interventions intended to increase teacher efficacy. In this article we will consider the potential of Professional Development (hereafter PD) as a stimulus for enhancing teacher beliefs about their capacity. We will illustrate our argument with data from a randomized field trial which examined the 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, i.e., "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 cognitive processes (especially goal setting), motivational processes (especially attributions for success and failure), affective processes (especially control of negative feelings), and selection processes (Bandura, 1993; 1997). Teachers who believe they will be successful set higher goals for themselves and their students, try harder to achieve those goals, and persist through obstacles. Individuals who believe 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 the task or with

activities similar to it, 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, reviews of research (Goddard et al., 2004; Ross, 1998; Tschannen-Moran, Wolfolk Hoy, & Hoy, 1998) demonstrate that teachers with high efficacy beliefs generate stronger student achievement than teachers with lower teacher efficacy. The effects of teacher efficacy on student achievement can be attributed to several factors.

First, those scoring higher on teacher efficacy measures are more likely to try out new teaching ideas, particularly techniques that are difficult, involve risks and require that control be 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 and reduce custodial control. Student achievement is higher because these management strategies are more effective in keeping students on task (Woolfolk, Rosoff, & Hoy, 1990).

Third, higher efficacy teachers are more successful because they attend more closely to the needs of lower ability students. Ashton, Webb, and Doda (1983) found that low efficacy teachers concentrated their efforts on the upper ability group, giving less attention to lower ability students who were viewed as potential sources of disruption. In contrast, high efficacy teachers had positive attitudes toward low achievers, built friendly relationships with them and set higher academic standards for this group than low efficacy teachers did. These practices contribute to higher achievement because lower ability students will be less certain about their competence and more influenced by teacher expectations.

Fourth, teacher efficacy leads to changes in teacher behavior which modify students' perceptions of their academic abilities. As student efficacy becomes stronger students become more enthusiastic about school work and more willing to initiate contacts with the teacher, processes that impact directly on achievement (Ashton et al., 1983; Ashton & Webb, 1986). Supporting this 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 the fall.

Finally, teacher efficacy influences student achievement through teacher persistence. Teachers with high perceived efficacy view student failure as an incentive to greater teacher effort rather than concluding 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 of these sources are mastery experiences, i.e., episodes in which teachers demonstrate to themselves that they are competent instructors, for example, by observing 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 vicarious experience (social comparison through observing the successes and failures of others), persuasion by peers and superiors (a weak source but important to teachers with little experience in a domain), and physiological and affective states. Teacher efficacy forms early in preservice experience and the early years of teaching, remaining relatively stable thereafter (Wolfolk Hoy & Spero, 2005).

Theory of Teacher Change

Figure 1 displays our theory of teacher change, developed in a qualitative study of a grade 8 teacher experiencing PD that focused on teacher self-assessments with explicit attention to

sources of efficacy information (Ross & Bruce, in press-a). At the core of Figure 1 is teacher self-assessment in which teachers observe their effect on student achievement, make a judgment about how well they attained their instructional goals, and reflect on how satisfied they are. These 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 the self-assessments made by PD participants. These 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.

Figure 1 About Here

Naturalistic Change in Teacher Efficacy

There have been uncontrolled manipulations that demonstrate that teachers' beliefs in their professional capacities are malleable. For example, a government-imposed de-tracking plan had an initially negative effect on the teacher efficacy of exemplary mathematics teachers (Ross, McKeiver, & Hogaboam-Gray, 1997). These teachers felt capable of teaching different ability groups in separate classes, but found their skills could not be readily integrated 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—they lacked a reservoir of mastery experiences in comparable settings. The study found that the negative effects of restructuring dissipated over time. There was a resurgence of teacher confidence 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. The renewal of teacher efficacy was associated with 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, the increases in teacher efficacy occurred when teachers accumulated experiences in which they (i) perceived themselves to be professionally masterful; (ii) observed teachers like themselves being successful; (iii) persuaded each other they could teach the new curriculum, and (iv) engaged in stress reduction practices. These four sources of efficacy information are the mediators that explain why de-tracking, and the coping strategies of these able teachers, influenced teacher beliefs about their effectiveness.

Effects of PD Training

A small number of studies have investigated the effects of PD on teacher efficacy. Given the stability of teacher efficacy (see reviews by Ross, 1998; Wolfolk Hoy & Spero, 2005), some researchers reporting an increase in teacher efficacy scores over the duration of a PD program have argued that score improvement is sufficient evidence of a program effect (Bolinger, 1988; Robardeck, Allard, & Brown, 1994). The assumption is questionable, particularly if the gains dissipate after the program ends (as found by Ohmart, 1992). The argument is more persuasive for those studies that demonstrate that teacher efficacy gains are higher among those who more 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. Effects were strongest for teachers identified as high 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. In this study teacher efficacy scores of treatment and control group teachers were equivalent on the pretest. However, the groups differed on prior in-service credits and sample attrition was significantly higher in the treatment than the control group.

Despite the methodological flaws in individual studies, prior research suggests that PD might contribute to higher teacher efficacy. First, virtually all these 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 . Studies that 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; Robardeck et al., 1994; Ross, 1994), thereby increasing opportunities for vicarious experience (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

The PD program we examined 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 teachers to implement unfamiliar instructional strategies, draw on disciplinary knowledge they may not have, engage lower ability students in abstract reasoning, and 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 that had as one of its goals the strengthening of 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 their ability to engage students?
2. Will the PD increase teacher efficacy beliefs about their ability to implement appropriate teaching strategies?
3. Will the PD increase teacher efficacy beliefs about their ability to manage students?

Method

Sample

The study was 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 with annual publication of results by school and explicit monitoring of improvement plans of 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 have not been introduced in Canada.

Over 95% of the students in the district were Canadian born, 52% were female, only 1% spoke a language other than English at home, 15% were identified as special needs, 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 randomly assigned to the treatment or control group.

Treatment teachers received the PD September-December 2003. Control teachers received the same PD at the end of the study. We used teacher attendance records to confirm that on the whole teachers participated at 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 they were in the fall PD group because the sessions were held at their school.

Sources of Data

The dependent variable, teacher efficacy, consisted of 12 items from the Teachers' Sense of Efficacy scale (Woolfolk Hoy, n.d.), adapted for mathematics teaching. There were four items for *efficacy for engagement* (e.g., "how much can you do to motivate students who show low interest in mathematics?"), four items for *efficacy for teaching strategies* (e.g., "how well can you implement alternative Mathematics strategies in your classroom?"), and four 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 a five-point scale anchored by "nothing" and "a great deal". The complete item set is in Table 1. We used this measure because it is becoming a standard instrument in the field: It had high reliability in previous administrations; there is evidence of 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 two weeks prior to the start of the PD and two 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 is 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 a six-point scale anchored by “strongly disagree” and “strongly agree”. Ross, Hogaboam-Gray & McDougall (2003) found this scale had high reliability ($\alpha=.81$ in two samples totaling 2600 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 how they used the text, in ways predicted by the survey. We also included other teacher background measures: *previous training in mathematics* consisted of four 4 items (e.g., “did you major in mathematics at university”) and *professional development in teaching mathematics* consisted of three items (e.g., “have you taken Additional Qualification courses that focused on mathematics education”).

Treatment

The PD consisted of one full day, followed by three 2-hour after-school sessions. We held sessions in three sites to reduce group size. Communication of mathematical ideas was the organizing theme, chosen because it impacts 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 mathematical knowledge 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 (in press-b).

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: active learning by teachers, using examples from classroom practice, collaborative activities modeling effective pedagogy, providing opportunities for reflection, practice and feedback, and focus on content. By increasing competence we anticipated that teachers would be more successful in the classroom, according to teachers' usual criteria, 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 right answer using conventional algorithms, we urged teachers to focus on the depth of conceptual understanding that students reached, the extent to which students contributed to the construction of their knowledge, and their ability to communicate mathematical ideas. To influence teacher criteria, we provided teachers with a rubric containing ten dimensions of mathematics teaching. For each dimension there were four levels of teacher practice, ranging from transmission teaching to standards-based teaching (Ross et al., 2003). We selected three dimensions for special attention. Experienced teachers modeled standards-based teaching using grade 6 tasks. While modeling, presenters encouraged teachers to judge their success in terms of familiar standards (e.g., student use of mathematical language) and those 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 these new standards for judging success. In

doing so 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 Experience Teacher efficacy increases when teachers observe their peers bringing about student learning. Our first strategy was to enlist experienced teachers from the same district to demonstrate new practices because models are more credible when they share characteristics with the learners. Our second strategy was to structure the debriefing sessions (through a series of prompts given to pairs and groups of four) to highlight classroom success so that teachers would see their peers as successful. Our third strategy was to present 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 those 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 this 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 what could go wrong.

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.²

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 we found to the mean $\pm$ 3.0 SD. 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 these criteria.

Table 1 reports 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 zero. We found that one item (“v31 How much can you assist families in helping their children do well in mathematics?”) fit the instructional strategies dimension better than the student engagement dimension. The remaining items all loaded on the scales identified by Tschannen-Moran and Woolfolk Hoy (2001).

Table 1 About Here

Table 2 displays 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 on entry to the study there were no significant differences between the treatment and control groups on any of the teacher efficacy variables. Nor were there statistically significant differences on the self-reported teaching practices survey. The lower panel indicates there were no differences between the two groups on previous mathematics education training. Table 1 also indicates that all teacher instruments were of adequate reliability (i.e., Cronbach’s α = .81-.86).

Table 2 About Here

Did teacher PD increase teacher efficacy beliefs?

Teacher efficacy was relatively stable over the duration of the study--pre-post correlations were $r=.61-.76$. We conducted a multivariate analysis of covariance using GLM 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 condition was not statistically significant, even though it explained 5.8% of the variance.

Table 3 About Here

Since the total sample in this study was relatively small, we decided to examine 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. For each of the dependent variables there was a large covariate effect. 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 teachers in the control group on all the teacher efficacy variables after posttest means were adjusted by pretest scores, even though only the classroom management efficacy differences were statistically significant.

Table 4 About Here

We examined whether the effect of the in-service on teacher efficacy for classroom management was moderated by prior knowledge of mathematics education (represented by attending one or more mathematics education conferences) or prior knowledge of the discipline (represented by taking one or university mathematics course). We ran a univariate analyses 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 (i) attending at least one mathematics conference, (ii) experimental condition, and (iii) the interaction of condition and covariate. We repeated the analysis replacing (i) 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 these analyses (not shown). Treatment teachers had greater confidence in their ability to manage mathematics classrooms than control teachers, regardless of whether teachers had received extra training in mathematics education or whether they had additional disciplinary knowledge.

Discussion

This study 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. We anticipated that PD that explicitly addressed four sources of efficacy information would have a positive impact. We found that there was an effect, although the results were statistically significant only for teacher confidence in managing students.

Standards-based mathematics teaching poses substantial management challenges. In traditional mathematics classes the task of teachers is to keep students attentive and on task; the role of students is to listen, watch and imitate. But in reform mathematics education the task of teachers is to guide student explorations and the role of students is to expand their conceptual grasp and integrate formal with practical knowledge. The 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 be molded during the lesson, requiring reflection-in-action (Schon, 1987). Third, the explorations of mathematical ideas may lead to areas where the teacher's understanding is shaky, challenging the teacher's status as the prime knowledge expert. This 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 students may resist.

The study 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 teacher 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 that were designed to influence sources of teacher efficacy information. Especially important, were two strategies designed to increase teacher opportunities for mastery experience: First, we strengthened their ability to manage classroom discussions by providing rich tasks, modeling the use of these tasks in simulations, requiring that teachers apply principles presented in the PD in their own classrooms, and 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. The results of the study 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, in press-a).

The finding of the current study is 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; Suppovitz & 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 (the pre-post correlation for the control group in this study across teacher efficacy dimensions was $r=.70$) so that even small changes are noteworthy.

A key strength of the current 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. Even though 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 of the current study are 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 shown 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 and the What Works Clearinghouse (2005), 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 studies focusing 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 mastery experiences. Invitations are the messages that we send to ourselves (and others) that indicate how able and valuable we feel about ourselves (and others). 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 both 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.

Implications for Practitioners

Finally, the practical implications of our study are to suggest directions for PD. Currently PD for mathematics teachers focuses on the acquisition of instructional skills, an 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. The results of our study indicate that PD that addresses sources of efficacy instrument can contribute to more confident teachers.

References

- Allinder, R. M. (1994). The relationship between efficacy and the instructional practices of special education teachers and consultants. *Teacher Education and Special Education, 17*(2), 86-95.
- Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement*. New York: Longman.
- Ashton, P. T., Webb, R. B., & Doda, N. (1983). *A study of teacher's sense of efficacy* (Final report to the National Institute of Education, Executive Summary). Gainesville, FL: Florida University.
- Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117-148.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.
- Bolinger, R. (1988). *The effects of instruction in the Hunter instructional model on teachers' sense of efficacy*. Unpublished doctoral dissertation, Montana State University, Bozeman, Montana.
- Doyle, W. (1999, April). *Teacher efficacy: Outcomes and antecedents*. Paper presented at the annual meeting of the American Educational Research Association, Montreal.
- Edwards, J. L., Green, K. E., Lyons, C. A., Rogers, M. S., & Swords, M. E. (1998, April). *The effects of cognitive coaching and nonverbal classroom management on teacher efficacy and perceptions of classroom culture*. Paper presented at the annual meeting of the American Educational Research Association, San Diego.
- Feuer, M. J., Towne, L., & Shavelson, R. J. (2002). Scientific culture and educational research. *Educational Researcher, 31*(8), 4-14.

- Fritz, J., Miller-Heyl, J., Kreutzer, J., & MacPhee, D. (1995). Fostering personal teaching efficacy through staff development and classroom activities. *Journal of Educational Research*, 88(4), 200-208.
- Fuller, F. (1969). Concerns of teachers. *American Educational Research Journal*, 6(2), 207-226.
- Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology*, 76(4), 569-582.
- Goddard, R. D., Hoy, W. K., & Woolfolk Hoy, A. (2004). Collective efficacy beliefs: Theoretical developments, empirical evidence, and future directions. *Educational Researcher*, 33(3), 3-13.
- Hill, H. C. (2004). Professional development standards and practices in elementary school mathematics. *Elementary School Journal*, 104(3), 215-231.
- Kline, R. B. (1998). *Principles and practice of structural equation modeling*. New York: Guilford.
- Levin, J., Nolan, J.F., Kerr, J.W., & Elliott, A.E. (2004). *Principles of classroom management: A professional decision making model*. Canadian Edition. Needham Heights, MA: Pearson.)
- Midgley, C., Feldlaufer, H., & Eccles, J. (1989). Change in teacher efficacy and student self- and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology*, 81(2), 247-258.
- Ohmart, H. (1992). *The effects of an efficacy intervention on teachers' efficacy feelings*. Unpublished doctoral dissertation, University of Kansas, Lawrence, Kansas.
- Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74(6), 625-637.
- Rimm-Kaufman, S. E., & Sawyer, B. E. (2004). Primary-grade teachers' self-efficacy beliefs,

- attitudes toward teaching, and discipline and teaching practice priorities in relation to the *Responsive Classroom* approach. *Elementary School Journal* , 104(4), 321-341.
- Robardeck, C., Allard, D., & Brown, D. (1994). An assessment of the effectiveness of full option science system training for third- through sixth-grade teachers. *Journal of Elementary Science Education*, 6(1), 17-29.
- Ross, J. A. (1998). The antecedents and consequences of teacher efficacy. In J. Brophy (Ed.), *Research on Teaching. Vol. 7.* (pp. 49-74). Greenwich, CT: JAI Press.
- Ross, J. A. (1994). The impact of an in-service to promote cooperative learning on the stability of teacher efficacy. *Teaching and Teacher Education*, 10(4), 381-394.
- Ross, J. A. (1992). Teacher efficacy and the effect of coaching on student achievement. *Canadian Journal of Education*, 17(1), 51-65.
- Ross, J. A., & Bruce, C. (in press-a). Self-assessment and professional growth: The case of a grade 8 mathematics teacher. *Teaching and Teacher Education*.
- Ross, J. A., & Bruce, C. (in press-b). The impact of a professional development program on student achievement in grade 6 mathematics. *Journal of Mathematics Teacher Education*.
- Ross, J. A., & Cousins, J. B. (1993). Enhancing secondary school students' acquisition of correlational reasoning skills. *Research in Science & Technological Education*, 11(3), 191-206.
- Ross, J. A., Hogaboam-Gray, A., & Hannay, L. (2001). Effects of teacher efficacy on computer skills and computer cognitions of K-3 students. *Elementary School Journal*, 102(2), 141-156.
- Ross, J. A., Hogaboam-Gray, A., & McDougall, D. (2003). A survey measuring implementation of mathematics education reform by elementary teachers. *Journal of Research in Mathematics Education*.

- Ross, J. A., McDougall, D., & Hogaboam-Gray, A. (2002). Research on Reform in Mathematics Education, 1993-2000. *Alberta Journal of Educational Research*, 48(2), 122-138.
- Ross, J. A., McKeiver, S., & Hogaboam-Gray, A. (1997). Fluctuations in teacher efficacy during the implementation of destreaming. *Canadian Journal of Education*, 22(3), 283-296.
- Schön, D. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. San Francisco, CA: Jossey-Bass.
- Smith, J. P. (1996). Efficacy and teaching mathematics by telling: A challenge for reform. *Journal for Research in Mathematics Education*, 27(4), 387-402.
- Stein, M., & Wang, M. (1988). Teacher development and school improvement: The process of teacher change. *Teaching and Teacher Education*, 4(2), 171-187.
- Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching*, 37(9), 963-980.
- Tschannen-Moran, M., & Woolfolk Hoy, A. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, 17, 783-805.
- Tschannen-Moran, M., & Woolfolk Hoy, A. (2002, April). *The influence of resources and support on teachers' efficacy beliefs*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.
- Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, 68(2), 202-248.
- Usher, E. L., & Pajares, F. (2005). *Inviting confidence in school: Sources and effects of academic and self-regulatory efficacy beliefs*. Paper presented at the meeting of the American Educational Research Association, Montreal.
- Waller, W. (1932). *The sociology of teaching*. New York, NY: Wiley.

- What Works Clearinghouse. (nd) *WWC Study Review Standards* [Web Page]. URL http://www.whatworks.ed.gov/reviewprocess/study_standards_final.pdf [2005, March 24].
- Woolfolk Hoy, A. (nd) *Research instruments* [Web Page]. URL <http://www.coe.ohio-state.edu/ahoy/researchinstruments.htm> [2006, July 6].
- Woolfolk Hoy, A., & Spero, R. B. (2005). Changes in teacher efficacy during the early years of teaching: A comparison of four measures. *Teaching and Teacher Education* , 21, 343-356.
- Woolfolk Hoy, A., & Spero, R. B. (2005). Changes in teacher efficacy during the early years of teaching: A comparison of four measures. *Teaching and Teacher Education* , 21, 343-356.
- Woolfolk, A. E., Rosoff, B., & Hoy, W. K. (1990). Teachers' sense of efficacy and their beliefs about managing students. *Teaching and Teacher Education*, 6(2), 137-148.

Table 1

Results of Principal Axis Factor Analysis of Teacher Efficacy Items

Item	Factor		
	Efficacy for Teaching Strategies	Efficacy for Engagement	Efficacy for Student Management
v22. How much can you do to motivate students who show low interest in Mathematics?	.171	.673	.001
v23. How much can you do to get students to believe they can do well in Mathematics?	.029	.892	-.075
v24. How much can you do to help your students value learning Mathematics?	-.092	.927	.063
v31. How much can you assist families in helping their children do well in Mathematics?	.468	.108	.056
v25. To what extent can you craft good questions about Mathematics for your students?	.901	.003	-.126
v29. How much can you use a variety of Mathematics assessment strategies?	.649	-.002	.064

v30. To what extent can you provide an alternative explanation or example when students are confused about Mathematics?	.659	-.017	.092
v32. How well can you implement alternative Mathematics strategies in your classroom?	.776	.035	-.003
v21. How much can you do to control disruptive behaviour during Mathematics?	-.058	-.034	.850
v26. How much can you do to get children to follow classroom rules about Mathematics?	.051	.221	.552
v27. How much can you do to calm a student who is disruptive or noisy during Mathematics?	-.024	-.019	.911
v28. How well can you establish a classroom management system for mathematics with each group of students?	.369	-.102	.481

Table 2

Description of Study Variables and Tests of Group Equivalence

	Group	N	Mean	SD	Alpha	t	df	p
Pre-Math Teaching	Treat	57	4.72	0.44	0.81	0.51	104	0.618
	Control	49	4.67	0.52				
Pre-Student Engagement Efficacy	Treat	57	4.13	0.62	0.86	-0.81	104	0.936
	Control	49	4.14	0.78				
Pre-Instructional Strategies Efficacy	Treat	57	4.01	0.56	0.82	1.13	104	0.263
	Control	49	3.88	0.58				
Pre-Classroom Management Efficacy	Treat	57	4.60	0.40	0.81	1.86	84.41	0.073
	Control	49	4.42	0.56				
Post-Student Engagement Efficacy	Treat	57	4.25	0.61	0.85			
	Control	49	4.13	0.65				
Post-Instructional Strategies Efficacy	Treat	57	4.02	0.55	0.84			
	Control	49	3.86	0.58				
Post-Classroom Management Efficacy	Treat	57	4.60	0.37	0.84			
	Control	49	4.33	0.54				
One or More Math Summer Institutes	Treat	57	14%					
	Control	49	10%					
One or More Math Conferences	Treat	57	56%					
	Control	49	50%					
AQ Math Course	Treat	57	3%					
	Control	49	2%					
One or More University Math Courses	Treat	57	48%					
	Control	49	65%					
M.Ed. Degree	Treat	57	11%					
	Control	49	8%					

Table 3

Effects of Professional Development on Teacher Efficacy

Independent Variables	Dependent Variables	<i>F</i>	<i>df</i>	<i>p</i>	<i>eta</i> ²
Multivariate Results					
Intercept	—	8.67	3,99	0.001	0.208
Pre-Engagement Efficacy	—	11.77	3,99	0.001	0.263
Pre-Inst Strategies Efficacy	—	26.78	3,99	0.001	0.448
Pre-Class Management Efficacy	—	10.01	3,99	0.001	0.233
Group	—	2.02	3,99	0.116	0.058
Univariate Results					
Corrected Model	Post-Engagement Efficacy	24.46	4,101	0.001	0.492
	Post-Inst Strategies Efficacy	38.18	4,101	0.001	0.602
	Post-Class Management Efficacy	18.9	4,101	0.001	0.428
Intercept	Post-Engagement Efficacy	3.29	1,101	0.072	0.032
	Post-Inst Strategies Efficacy	4.61	1,101	0.034	0.044
	Post-Class Management Efficacy	26.27	1,101	0.001	0.206
Pre-Engagement Efficacy	Post-Engagement Efficacy	32.69	1,101	0.001	0.245
	Post-Inst Strategies Efficacy	5.716	1,101	0.019	0.054
	Post-Class Management Efficacy	3.186	1,101	0.077	0.031
Pre-Inst Strategies Efficacy	Post-Engagement Efficacy	0.365	1,101	0.547	0.004
	Post-Inst Strategies Efficacy	66.93	1,101	0.001	0.399
	Post-Class Management Efficacy	0.182	1,101	0.670	0.002
Pre-Class Management Efficacy	Post-Engagement Efficacy	5.306	1,101	0.023	0.050
	Post-Inst Strategies Efficacy	0.008	1,101	0.930	0.001
	Post-Class Management Efficacy	24.22	1,101	0.001	0.193
Group	Post-Engagement Efficacy	0.792	1,101	0.376	0.008
	Post-Inst Strategies Efficacy	1.119	1,101	0.293	0.011
	Post-Class Management Efficacy	6.135	1,101	0.015	0.057

Table 4

Post Teacher Efficacy Scores Adjusted by Pretests

	Adjusted Posttest Means		Mean Differences
	Treatment Group	Control Group	
Engagement Efficacy	4.23	4.15	.08
Instructional Strategies Efficacy	3.98	3.90	.08
Class Management Efficacy	4.56	3.78	.58

Figure 1: Model of Teacher Self-assessment as a Mechanism for Teacher Change (from Ross & Bruce, in press-a)

Endnote

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² We ran Missing Values Analysis on the data. This procedure uses regression methods to estimate missing values, using 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 is not stable (Woolfolk Hoy, n.d.). All items were aggregated 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, using separate sample t-tests for each variable. Conducting multiple t-tests inflates type I error; it increases the likelihood that statistically significant differences will be found. The usual defense is to apply a Bonferroni adjustment. However, since we were predicting no differences between the treatment and control groups the more rigorous procedure is to use unadjusted alphas. The research question was addressed in a multivariate analysis of covariance using GLM: the posttest scores on three dimensions of teacher efficacy; the pretest scores were covariates; the independent variable was experimental condition.